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Approaches to studying and the effects of mathematics support on mathematical performance

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TABLE OF CONTENTS

Abstract

The concern over undergraduate engineering students' mathematical skills and the means of addressing this through the provision of mathematics support is the main driver of this research. With the emergence of mathematics support within mathematics education there has been an associated research community interested in measuring the effectiveness of mathematics support provision. Recent studies have measured improvements in mathematics performance for students who have used mathematics support against those who have not by comparing prior mathematical ability against examination results. This does not address the issue of individual differences between students and resulting changes in mathematical ability.

However the provision of mathematics support for individual students is resource intensive hence evaluation of the effectiveness of the support is essential to ensure resources are efficiently used. This mathematics education research examines the effectiveness of mathematics support in addressing the mathematics problem. It does this by considering individual differences and the mismatch of mathematical skills for studying at University by analysing the effectiveness of mathematics support in improving mathematical skills.

The dataset for the analysis comprises of over 1000 students from a Scottish Post-92 University, over 8% having made use of mathematics support, and nearly 2000 students from an English Russell Group University, with just over 10% having made use of the support. It was discovered that in both sets of data the students who came for mathematics support in comparison to their peers had a statistically significant lower mathematical skills base on entry to their course, and at the end of their first year had improved their mathematical skills base more than their counterparts. Although the analysis is based on data from UK Universities we believe the findings are relevant to the international community who are also engaged in the provision of mathematics support.

However, this approach is open to criticism because it does not use a randomised sample. The sample was made up of *nearly* of all the students whose entry and exit (end of years 1 and 2) mathematics qualifications were known, some of whom had made use of mathematics support and some who had not. Hence a further study was undertaken to examine students' preferences for different approaches to study as a differentiating factor. 122 students at the English Russell Group University completed a modified version of the Approaches to Study Skills Inventory for Students questionnaire, 34 of whom had used mathematics support. Considering performance of mathematics support students and non-mathematics support students in the light of their approaches to studying provides a means of addressing the bias introduced by the non-randomised data.

The modified Approaches to Study Skills Inventory for Students questionnaire has two new subscales which are used to measure procedural deep and procedural surface approaches. These subscales are introduced to help provide a finer characterisation of approaches to studying in the mathematics discipline. It was discovered that the procedural deep subscale achieved internal reliability and as a result was placed within the overall deep approach scale but the procedural surface subscale did not achieve reliability and was discarded from further analysis in this study. Using these categories, it was found that the students who had shown a desire to gain deeper understanding were making more use of mathematics support. Additionally, changes in approaches to studying were investigated for a group of 25 students, out of the original 122, who had completed a shorter version of the questionnaire at the end of semester 1 as well. It was discovered that after one semester at university these students had changed their approaches to studying to a more surface approach. It is possible that the assessment process in Higher Education is more accommodating to students who can switch between approaches, especially in engineering where the learning of processes and meaningful understanding go hand-in hand. The change in approach to a more surface one in their first year adds to that the discussion that the deep approach is not necessarily better suited at level 1 for successful studying. Whether this is driven by the Higher Education assessment requirements is beyond the scope of this thesis but is worth consideration for future work.

In conclusion, mathematics support was being used mainly by students who had weaker mathematics than their peers at both Institutes. However, there was another group of students namely those with a higher level of mathematical skills who were making use of the support centre but these were a minority in this study and a deeper review has not been undertaken here. We found that students taking advantage of mathematics support improved on their mathematical skills more than the students who had not made use of the support, though the improvement was not large enough to lead to out-performing students not making use of mathematics support. Additionally, students who had initially shown a desire to gain a deeper understanding in their learning had changed to a more surface approach after a semester at university.

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1 Introduction

Several reports and research outputs have indicated that there is a problem of insufficient mathematical ability amongst undergraduates, especially in science and engineering (Crowther, Thompson *et al. 1*995; Sutherland and Pozzi 1995; Hunt and Lawson 1996; Engineering Subject Centre 2000; Hawkes and Savage 2000; Smith 2004; Pell and Croft 2008). The reasons identified for this problem are a lack of adequate mathematics qualification at entry to Higher Education (HE), changes in mathematics GCSE and A-Level qualifications and inhomogeneity in mathematical attainment. There had also been a drop in pupils taking mathematics A-Level (Walport, Goodfellow *et al*. 2010) and the reduction in numbers of mathematics and science graduates which is leading to a lack of good mathematics teachers (Grove 2005), which in turn is expected to lead to pupils with weaker mathematical skills upon leaving school. At HEIs extra-curricular mathematics support is being provided to tackle the mathematical deficiencies of students on degree programmes with a numerate element to strengthen their mathematical skills sufficiently for success on their chosen programme of study (Lawson, Croft, *et al*. 2003).

The effectiveness of mathematics support has recently become a subject of coordinated research (Croft 2009) and although these studies generally indicate the positive effect of mathematics support, there may be no accurate prediction of the long term effects on the students' understanding of and development in mathematics (Samuels and Patel 2010). Measuring mathematical ability is not considered straightforward and is too wide an area to cover sufficiently within this research therefore measuring effectiveness here is carried out in terms of mathematical *skills* measures rather than ability. Mathematical skills are measured using mathematics qualifications and mathematics test results. The provision of mathematics support for individual students is a resource intensive way of strengthening students' mathematical skills and if provided without evaluation of its effectiveness can viewed as a resource of questionable efficiency. Hence identifying reliable means of measuring effectiveness of mathematics support services is important. These means can then be used to ensure that services deliver definable benefits to students that are cost effective.

1.1 The mathematics problem

The majority of the teaching material presented to students tends to be written for the *traditional* student (entering HE straight from School with appropriate A-Level entry qualifications) with reasonable ability, whose intention is to leave HE with a specific agreed qualification. However, with the move towards widening participation whereby universities are under pressure or are persuaded to recruit more students from a non-traditional educational background to maintain their funding grants (DFES 2003) there is not only awareness amongst academics of the need for more flexible teaching material and methods but also the need for development of more appropriate material delivered in a variety of modes (Khan 2000). These developments, though they have good intentions to provide better access for a more diverse type of student population needing a variety of options to study at a time that suits them, have increased the need for extra-curricular support to help fill the gaps in mathematical skills known to exist (Hobson 2008) and /or skills not covered within the programme but assumed as known.

The diversity of the entry qualifications and range of backgrounds of students now entering university and the associated variability in mathematical skills for HE requires a parallel diverse mode of teaching to better fit the needs of the students. A differentiated approach to teaching, whereby the students' ability is taken into account, is needed to accommodate their diverse needs and to allow for a more individualised learning experience.

The data in this research is from a Scottish Post-92 university, the Robert Gordon University (RGU) and a Russell Group English university, the University of Sheffield

(UoS). Due to the differences between the Universities the profiles of the respective student cohorts are vastly different with RGU having a greater number of widening participation students compared to the UoS cohort. Hence a direct comparison between the Institutes is not possible and not attempted; only the analysis of the effectiveness within the Institutes that has been undertaken.

Students at RGU would traditionally enter with Scottish Highers and the UoS students with A-Levels but over the past decade, entry routes to HE have been changing (Aston and Bekhradnia 2005) and this trend has an impact on HE because much of the material presented to students is designed for traditional entry qualified students. Therefore non-traditional entrants, who can be students from differing age-groups (than the expected school-leaver), with diverse entry qualifications, from zones of socio-economic deprivation or ethnic minorities, from the beginning have to deal with programmes that do not take into account their preferred approaches to studying, their ability and their prior experience. As lecturers tend to target their material for the adequately able student, this means that not only do the students with poor entry skills require supplementary support and time for this additional support, but support is also needed for the brighter students who are not sufficiently challenged (Croft and Grove 2006).

The factors that negatively affect students with non-traditional backgrounds with respect to engaging with their programmes of study necessitate some form of transitional support to aid study at HE level. This refers to a longer term on-going support rather than just simple induction at the beginning of study.

In mathematics and related disciplines there is evidence that students with non-standard entry qualification struggle to proceed successfully (Symonds, Lawson *et al.* 2008) and there are other entry routes for students due to Widening Participation initiatives e.g. work experience, vocational qualifications, access or foundation courses that also need to be considered when designing and delivering programmes of study. In these circumstances, flexible and individualised mathematics support is a valuable, if not essential, resource.

1.2 Mathematics support at universities

The need for additional mathematics support has been recognised for at least the last 20 years (Beveridge and Bhanot 1994; Lawson, Croft *et al.* 2003). Some of the reasons for this are: inadequate preparation in schools, widening participation and a lack of understanding by lecturers of the true meaning of GCSE and A-Level grades (Lawson, Croft *et al.* 2003; Lawson, Tabor *et al*. (1995); Cuthbert and MacGillivray 2007).

The methods of mathematics support vary from university to university (Lawson, Halpin *et al.* 2001): some have introduced changes in the main programme of study which has meant rewriting material to include streaming for a variety of mathematical abilities at entry level and/or to include revision/bridging the gap teaching sessions to bring students to a leveller plane, but this puts additional pressure on lecturers to cover the required material within a certain period and pressure on students to study this additional material. An alternative is to reduce the level and amount of mathematics teaching within the programme but this would lead to the lowering of standards of UK degrees which is undesirable.

Thus many universities, more than 60% in the UK (Perkin and Croft 2004), provide additional support in parallel with the mainstream programme, but this again, if not presented appropriately, puts added pressure on students with weaker mathematical skills who will already be feeling stressed by if not overwhelmed by the level of mathematics required. Where dedicated staff are not in place to provide mathematics support, academic staff have made themselves available to students to help with mathematics problems. The latter is possibly the ideal provision but unsustainable, unless the academic belongs to a faculty with a good budget and sympathetic management. However, the current ‘cuts’ in HE make sustainability of the provision of mathematics support a key aspect for consideration. The focus for this research on the effectiveness of mathematics support and the effect of students' approaches to studying on engagement with mathematics support will, it is hoped, feed into the sustainability debate.

The critical stance for this study is as a mathematics education researcher to consider the current methods of measuring effectiveness of mathematics support and develop a suitable *Approaches to Studying* (*AtS*) instrument to use to refine the measurements for effectiveness. One of the constraints of the research is the use of historical data from RGU for a review of effectiveness; where there was no opportunity for further collection of data or for filling in missing data. Another is that the *AtS* data collection had not been piloted hence the analysis in this research is offered only as a trial of the *AtS* instrument. However, the *AtS* analysis as it is, is interesting and does add to the body of research in mathematics education and, in particular, mathematics support. Recall that measure of changes in students' ability in mathematics is only inferred in terms of changes in mathematical skills.

1.3 Effectiveness and sustainability of mathematics support

To help alleviate the sustainability issue of mathematics support, a better match for supply to demand is desired to reduce the amount of resource intensive one-to-one mathematics support needed. This research explores the use of students' *AtS* to improve appropriateness of mathematics support methods. In that it would help decide on individualised learning experiences for students within the resources available and to strengthen the measure of the effectiveness of mathematics support beyond just the accumulation of knowledge towards learning development (Cardella 2008).

The effectiveness of mathematics support on students' mathematical skills will be measured; this includes researching the value of mathematics diagnostic testing and follow-up to address the issue of attrition due to deficiencies in mathematical skills (Lawson, Halpin *et al.* 2001; Patel and Little 2006). The added factor of this research will be the use of students' *AtS* scores and how these can be used to present mathematics support more effectively and efficiently. This will also help identify sample bias (i.e. mathematics support users may have inherently better motivation) through consideration of *AtS* scores and exploration of the effect on progression on the main programme of study and the effect on progression and changes in *AtS* resulting from mathematics support intervention and a semester of studying at university.

The data from the two universities is from the engineering faculties and is selected because this is the group for whom mathematics support is more relevant, but the methods of the research are expected to be useful and transferable to other disciplines. This research examines the data with respect to entry qualifications and resulting progression to note any key findings.

The most effective means of delivering fundamental mathematics topics will be identified by reviewing relevant literature and by identifying any trends and/or relationships between influencing factors through data analysis. These factors will then be prioritised and a number selected for a deeper analysis on how they affect student learning, and eventually the selected factors will be applied in the mathematics support environment. A critical appraisal of developing mathematical skills will underpin the analysis of influencing factors. Criteria for assessing 'understanding' are limited to measuring and comparing the *AtS* scores, the higher scores in the deep approach indicating ability to transfer skills learned to real world settings, thus exhibiting understanding. Higher scores in the surface approach indicate the learning of processes to apply to appropriate problems without deep understanding.

A questionnaire to elicit a multiple component construct of students' approaches to studying is described and related to the current research literature into approaches to studying in the context of mathematics education.

The research will lead to the recommendations for the development of a model for learning and teaching of mathematics in a mathematics support environment with a longer term potential development of a refinement model through evaluation. Evaluation needs to consider the students and their place within this research on mathematics support.

1.4 Student: the individual and diversity of entry qualifications

The Individual occupies a key position in mathematics support since the student's very specific mathematical skills needs are addressed (Samuels and Patel 2010). Situating the individual at the heart of learning is desirable as learning theories have highlighted. The process of education is, according to Dewey (1897), *continuous*; he explains it as a process that begins unconsciously almost at birth, continually shaping the individual's powers, saturating his consciousness, forming his habits, training his ideas and arousing his feelings and emotions. Piaget (1955) describes it in terms of development *stages* including movement from the egocentrism to the conservationism position (being able to see things from a different perspective) and Vygotsky (as cited by Pass 2004) described the learning development of a child on a *social* conscious level as being able to turn it into speech (able to communicate ideas) and producing a sociological activity. These writers along with Schoenfeld (1992) highlight a strong association between learning, the individual and the *social activity*. The general educational theory is only provided in this thesis briefly to introduce the importance of the student's individualism.

With this in mind the recent move towards widening participation (Roberts 2002; Reed, Gates *et al. 2*007) makes it harder to provide specific support to students when student numbers and the variety of ability are high and wide. This change affects both students and academic staff. Difficulties increase for the student as they have very little time to process new information and combine with their prior experiences to gain understanding and hence construct their learning. For academic staff the effective contact time per student is reduced as student numbers rise. The challenge for HE at this stringent time is to continue providing quality experiences and opportunities appropriate to the student's current capacity to learn (Vygotsky 1934; Attwood 2010) and to allow for constructive learning. To evaluate learning development in mathematics the analysis of student's progression is undertaken with regard to mathematics support usage.

1.5 Proposed analysis

Record of mathematics support usage, students' mathematics related entry qualifications and other background information were collected. This, along with the diagnostic results, will be used to measure the student's mathematical skills, at the start (entry) of their programme of study. The end-of-year mathematics module results provide the results at the end of a year of study (exit). Relationships will be examined between these factors and the student's preferred approaches to studying scores, noting any trends and/or bias (Samuels and Patel 2009).

The assumption the author is making is that initially students will prefer a more surface approach but once basic skills have been mastered they can be combined to solve applied mathematical problems and even used to develop new solutions and hence develop a more deep approach.

Another area of interest is the predictive value of the independent variables i.e. mathematics entry qualifications, mathematics diagnostic test result and approaches to studying (*AtS*) score (Figure 1) on student progression (Figure 2) and the contribution to progression value of mathematics support and learning development value of mathematics support. The learning development will be measured by examining students' *AtS* scores, looking for changes in development and value added after mathematics support intervention.

The intervention being measured is mathematics support. The main dependent variables are module results and changes in students' *AtS* scores after mathematics support intervention. These variables are selected to help address the issues of:

inadequate mathematics entry qualifications, changes in required mathematics entry qualifications and the inhomogeneity in mathematics attainment. This research addresses content within students' degree programmes and as such the students are exposed to other interventions as well, not least main curriculum teaching and self-study. These are not examined in detail here but are acknowledged to be present factors.

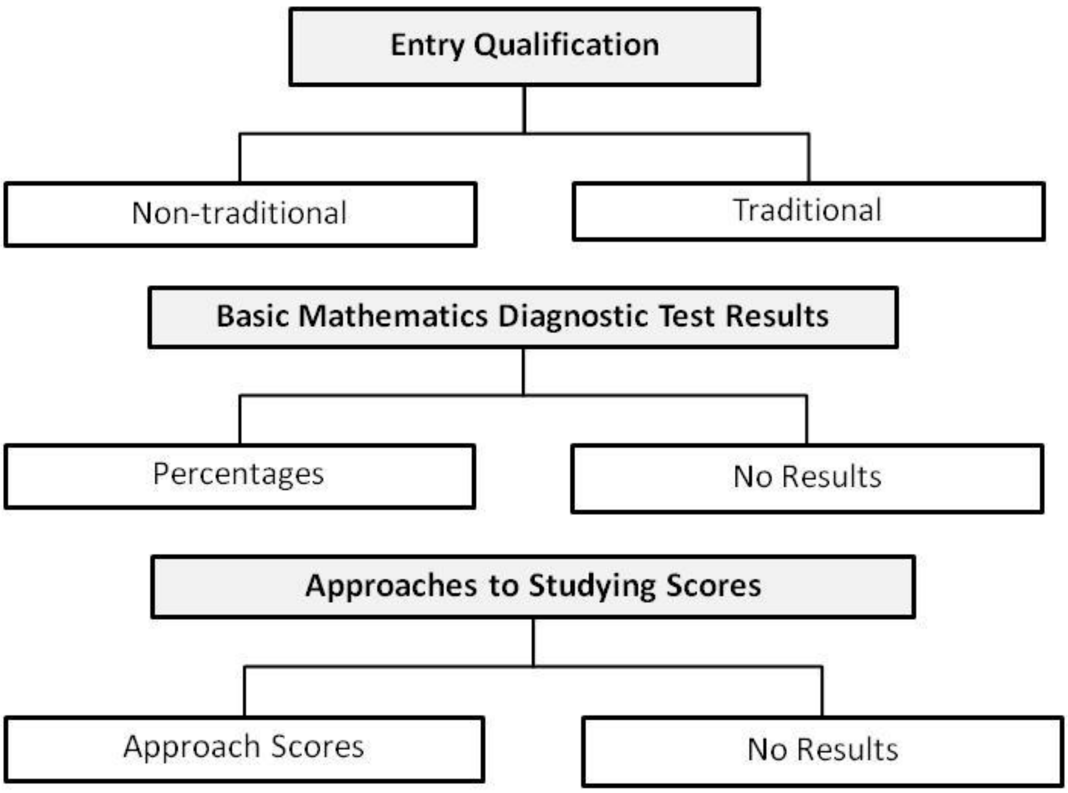


Figure 1 - Main Independent Variables

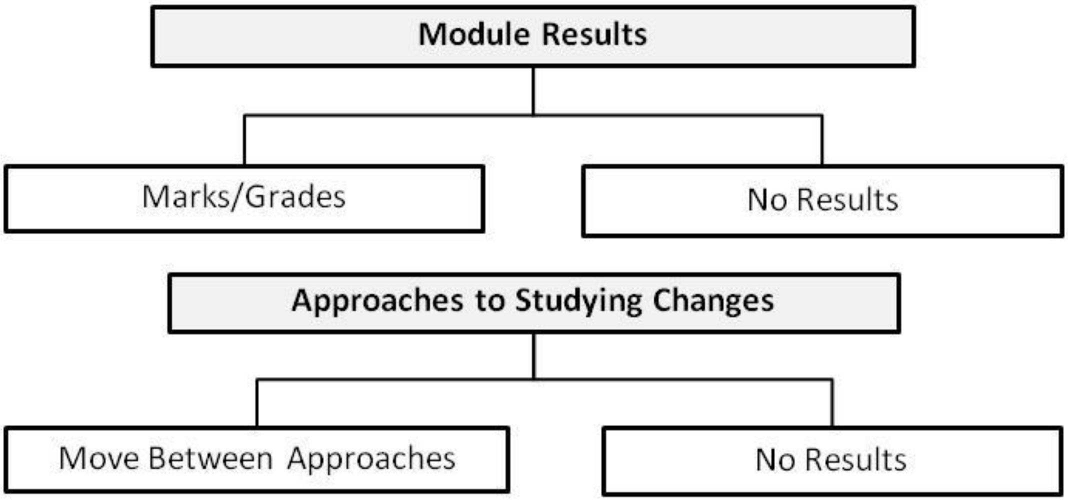


Figure 2 - Dependent Variables

1.6 Research findings and discussions

The main findings of the research are that overall students who made use of mathematics support had weaker mathematical skills to begin with, though there was a very small number of who had strong mathematical skills. The motives for engaging with mathematics support for these students vary greatly; for one it might be a matter of survival and for another it might be the 'extra' needed to get as near a perfect score as possible.

The value added effect of mathematics support has been to improve students' mathematical skills over the first year enough to bring them to at an almost equal level with those who started with a higher proficiency. At the end of the second year for mathematics support students, at RGU, the results had improved greatly however this was not the case at UoS, and as stated earlier the author has not been able to re-visit the RGU data to ensure completeness of the dataset. Therefore this result is not deemed reliable and needs further examination.

The results of the *AtS* measure showed that in the first year of the programme, students adapted their approaches to a more surface approach from the deep approach, indicating the switching of approaches to suit requirements and pressure.

1.7 Dissertation overview

Chapter 1 gives an overview of both the research and the structure of the other chapters.

Chapter 2 provides the literature review of the surrounding work and research. This includes concerns over the lack of mathematical skills amongst engineering undergraduates, emergence and development of mathematics support, theories of learning and *AtS* measurements development.

Chapter 3 describes the methodology used for this research and how the effectiveness of mathematics support on students' mathematical skills was measured and analysed. The analysis detailed was in three stages: the first stage considered the mathematics support users' characteristics, stage two looked at the influence of various factors on students' performance on mathematics modules and stage three considered models for improving the effectiveness mathematics support.

Chapter 4 provides details of the data sources and collection, the sources being university records, mathematics support usage data, diagnostic test results, module results and *AtS* questionnaire scores.

Chapter 5 contains stages one and two of the analysis of the research on the effectiveness of mathematics support and value added. The *AtS* factor added another dimension to the analysis (restricted to UoS), first to remove any bias introduced by sampling and secondly to profile mathematics support users and finally to examine appropriateness of the *AtS* scales in a mathematics support background.

Chapter 6 considers the third stage of the analysis, the discussion and the formation of models for measuring the effectiveness of mathematics support and predicting students' performance on mathematics modules.

Chapter 7 considers implementation of the models developed in chapter 6 for improved mathematics support and prediction of performance. It makes recommendations and suggests further work on improving these models which could address the limitations of this research.

2 Literature review

The importance of adequate mathematical skills for engineering students has been a concern for many years (Sutherland and Pozzi 1995; Hawkes and Savage 2000) and continues to be of concern (Smith 2004, House of Commons Committee of Public Accounts 2008). In order to improve the supply of numerate graduates the Roberts (2002) review *SET for success* was commissioned by the Government to consider the UK's future in research and innovation which was under pressure due to a lack of high quality scientist and engineers. The review highlighted the lack of graduates in subjects with a high numerate content i.e. Physics, Mathematics, Chemistry and Engineering. It further highlighted a shortage of Physical Sciences and Mathematics teachers/lecturers. Mathematics A-Levels as a percentage of all A-levels dropped from24% to 17.7% over the years 2001 – 2004 (see table 1).

	2001 %	2002 %	2003 %	2004 %
A-Level Students	100	100	100	100
Mathematics	24.0	17.5	17.2	17.7
Further mathematics	2.3	1.8	1.8	1.9
English	33.3	29.7	28.3	28.4
Physics	12.7	11.4	10.4	9.6
Geography	15.4	13.2	12.7	12.2

Table 1 - Participation in A-Levels 2001-2004, extract from report by Matthews and Pepper (2005)

Next to Physics, Mathematics had the lowest rate of non-conversion from AS to A-Level, conversion dropping from 82.6% in 2001 to 66% in 2004. The physics conversion rate dropped from 88.2% in 2001 to 65.2% in 2004. The main cited drop-outs and non-conversion reasons given by pupils in the report on *Evaluation of participation in A-Level mathematics* by Matthews and Pepper (2005) were not that it was a hard subject but that it would have been hard to get a high grade in Mathematics compared to other subjects. Thus pupils opted for easier higher grades in the lesser mathematical subjects.

The More Maths Grads project (2007-2010) was set up to increase engagement with mathematics education by students (Grove 2005; Flavin 2009) an increase from 2004 figures can be seen in Chart 1) (Reeves 2007).

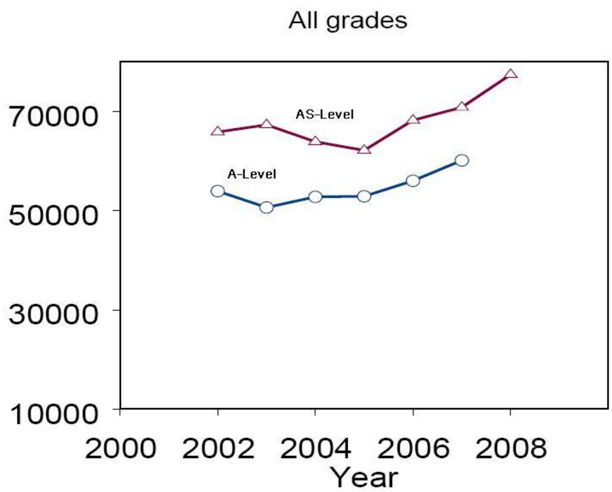


Chart 1 – A-Level vs. AS qualifications extracted from MMG Statistical Report (Reeves, 2007)

Further reports and reviews have been written to address the lack of adequately prepared engineering undergraduates by tackling the need for sufficiently qualified and able mathematics teachers/lecturers and numerate graduates and to increase engagement by HE to increase numbers of numerate graduates, some endorsing additional support at University.

> *"There is much that universities can do to improve retention … **They can provide additional academic support for students, for example for those struggling with the mathematical elements of their course.** Student access to tutors who can provide pastoral and academic support is important, especially as the numbers of students entering higher education institutions increases."*
>
> House of Commons Committee of Public Account (2008: p3)

This chapter begins by highlighting the issues related to the lack of adequate mathematical skills in HE, especially for engineering undergraduates, and provides an overview of the provision of mathematics support to address the need. This chapter will detail general approaches to learning/teaching mathematics and will conclude with a review of students' approaches to learning and studying.

2.1 Tackling concerns relating to the mathematical skills of undergraduate engineers in Higher Education in the United Kingdom

The need for ensuring mathematical preparedness for entrance to universities has been noted from the early 1990's (LMS., IMA., RSS. 1995) and this is a requirement in most disciplines but crucial for science and engineering. The main concern in this study is the mathematical deficiencies faced by engineering students where a good grasp of mathematics is essential (Sutherland and Pozzi 1995) for successful completion of the main programme of study and real understanding of the discipline. In the government's White Paper *The Future of Higher Education* (Clarke 2003) the long term strategy for HE relevant to this study can be summarised as the *strengthening of research* and *knowledge transfer*, *rewarding excellent teaching* and *expanding recruitment* in order to *benefit the individual* and the *economy's higher level skills*. Financial support for those from disadvantaged backgrounds is included to enable attainment and aspiration within that group. In particular the mismatch of school mathematics to undergraduate mathematics (Roberts 2002) has caused the need for more suitable bridging programmes to help make the transition. Clarke (2003) set a target to increase the percentage of 18-30 year olds in HE to 50% by 2010. The Figure 3 extract (HEFCE 2010, p14) shows an estimated increase to 36% in 2009[1], participation by the less advantaged group having increased more than participation by the more advantaged. The outcome of the Clarke report was an increase in investment in HE to the extent of 6% over and above inflation (at time of writing report) for three years, funding for student support rose with a generous financial settlement in order to improve opportunity for personal and intellectual fulfilment, increased earning potential and to have more engaged citizens within the communities (Clarke 2003).

[1] At the time of reviewing the dissertation in 2011 the government had changed its policy on this investment and the 50% in HE drive is no longer in place

Chart 2 has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Chart 2 – Trends[2] in young participation for England extract (HEFCE, 2010)

Along with this increase in student numbers has come an increase in diversity of mathematical ability amongst the students, the two main reasons being; widening participation (Patel 2001; DFES 2003) and changes in school mathematics (Sutherland and Pozzi 1995). Even with the funding in place to address this situation it would still take a number of years before the effects of any initiatives to address these issues can be seen and appreciated. One of the recommendations in the Smith (2004) and House of Commons Committee of Public Account (2008) reports to address the mismatch of school-mathematics enabling adequate transition to University-mathematics was the provision of mathematics support in addition to curriculum mathematics.

Many of the mathematics support activities are funded via the widening participation initiatives which assist transition. However with the current financial economic crisis due to the national debt, the public sector is currently getting less funding (Mandelson 2009) and as a result HEI's are required to compete more than ever and are seeking to meet their funding needs by becoming more efficient and effective. One of the outcomes of this research will be to help this need by informing on the provision of effective mathematics support, and as the economic crisis is international the impact value of the research will also be relevant to the international community as well.

[2] P = predicted, E = estimate

Now with the new coalition government these priorities have seen a further change whereby encouraging young people from a disadvantaged background to enter HE through the Aim Higher programme comes to an end (Attwood 2010) and the increase in fees by Universities (Baker 2010) is likely to lead to a return to an elitist system of education. However the latter is not the focus of this research and is not discussed any further except to acknowledge that these changes will in time bring different priorities for the mathematics support community. Yet the pressure for greater numbers of engineering graduates still remains a priority as a report to the House of Commons highlights:

> *"Some subject areas are affected by both low demand and poor retention. A range of science, technological, engineering and mathematical courses are strategically important but provision of courses is vulnerable because of low demand. Taken as a whole,* ***retention in these subjects is worse than in other subjects****, for both full-time and part-time students. For example, the first-year continuation rates for Mathematical and Computer Sciences and for Engineering are around three percentage points below average. Many* ***students in these subjects require additional academic support in mathematical skills****. Universities are responding by introducing innovative ways of teaching, for example project-based learning, and mathematics 'drop-in' skill centres are becoming more common."*

(House of Commons Committee of Public Accounts 2008: p15).

There is consequently pressure on HE practitioners to first protect the accessibility of education and secondly to highlight the benefits of mathematics support.

The entry qualifications requirements for engineering students have gone through changes leading to a diverse range of entry qualifications, which in turn has led to a wider range of mathematical skills amongst engineering students. The skills gap between what students are expected or need to know on arrival at university and what they actually know is of concern to students and lecturers (House of Commons Committee of Public Account 2008; London Mathematical Society 1995). The result of this for lecturers has been the need to present their material such that it can be accessed by students with differing ability differing prior experience. Additionally there needs to be an understanding of the differences in content of the Mathematics A-Level by teaching staff to appreciate the varying understanding of and ability in mathematics (Perkin, Pell *et al. 2*007).

A good understanding of mathematics is important as it underpins much of engineering principles (Quality Assurance Agency for Higher Education 1996). Unfortunately variation in entry qualifications and ability requires further measures to make up for the deficit which places additional pressure on what will already be an overcrowded curriculum for students with weaker mathematical skills. Finding means of gaining adequate understanding of mathematics within the time available to students is the focus of the next section.

2.2 Learning mathematics

To become a 'good' mathematician one needs to be proficient in using the 'tools of the trade' or *resources* as Schoenfeld (1992) puts it, for example a good grasp of the multiplication tables and ability to switch between decimals and fractions. Without these fundamental skills the crucial mathematical skills such as the notion of converting calculus problems into algebraic ones for easier manipulation, as in Laplace transforms of differential equations, is beyond reach. With a strong comprehensive skills base the students will be able to confidently and *flexibly* apply mathematics in the real world, making the graduate more employable. Of course it is not just the learning of processes that is necessary but making connections by *efficiently* and *flexibly* using *resources* and developing mathematical thinking (Schoenfeld 1992).

The process of education according to Dewey (1897) is continuous; he explained it as a process that begins unconsciously almost at birth, and is continually shaping the individual's powers, saturating his consciousness, forming his habits, training his ideas, and arousing his feelings and emotions. Piaget (1937) describes it in terms of development stages progressing from egocentrism to conservationism leading to the child being able to see things from a different perspective or position. Vygotsky (1934) described the learning development of a child on a conscious level to being able to turn it into speech and communications making it a sociological activity, whereby the child interacts and develops independently to a certain extent and is further aided to develop with assistance from 'other' more able children/adults within his *zone of proximal* development. These writers highlight a strong association between learning and the *individual.* Schoenfeld (1992, p3-4) puts it this way:

> *'Mathematics is an inherently social activity, in which a community of trained practitioners (mathematical scientists) engages in the science of patterns — systematic attempts, based on observation, study, and experimentation, to determine the nature or principles of regularities in systems defined axiomatically or theoretically (pure mathematics) or models of systems abstracted from real world objects (applied mathematics). The tools of mathematics are abstraction, symbolic representation and symbolic manipulation.'*

Personalised experience of mathematical learning becomes hard to accomplish via prescriptive and set teaching programmes because of the recent move towards widening participation (DFES, 2003). When students as individuals require different times to process new information and combine it with prior experiences for understanding and construction of learning, set teaching programmes do not provide the differentiation needed by *individuals*. Additionally, the contact time with lecturers becomes more limited as the student/staff ratio increases as more students are recruited onto University degrees. The challenge for HE is to provide quality experiences and opportunities appropriate to the student's current capacity to learn (Vygotsky 1986) and to allow for constructive learning.

Schoenfeld (1992) identified five things that make up mathematical thinking: core knowledge, problem solving strategies, effective use of one's resources, having a mathematical perspective and engagement in mathematical practices. Cardella (2008) also emphasises the need for *all* aspects of mathematical thinking to be utilised in order to provide a rounded understanding of engineering mathematics.

There have been attempts to introduce methods to improve the teaching of engineers using problem solving (Rossiter and Biggs 2008) e.g. teaching of mathematics by engineers rather than mathematicians, integrating mathematics better with engineering (Patel and Rossiter 2011) and uniting mathematics and engineering by introducing mathematical modelling courses (Cardella 2008).

Contextualising processes will help students to link theory to practice and this is especially relevant to engineering students whose application of mathematics is practical. According to Piaget and Vygotsky learning had a *social context* as well, and our daily life requires us to be able to apply our learning to our environment and community by interpreting news or information reports to align our learning to the demands of life.

Brown and Thomson (1973) have defined contextualising by dividing the processes into three elements; *mass, significance* and *doingness* which enable learning i.e. in order for students to learn and retain the knowledge of a subject it is necessary that there be a proper balance among the elements: *Mass* (any actual physical universe mass which is present or referred to in the subject, the setting), *Significance* (ideas, relations, meaning, etc. in the subject) and *Doingness* (any actual involvement in this study). Unfortunately in mathematics there is an emphasis on significance to the virtual exclusion of the mass and to some extent *doingness*, thus, making the subject difficult for individuals. Although not normally a problem in mathematics it should be noted that too little significance can present just as big a problem as not enough mass. A means of introducing the theory of using mass, significance and *doingness* in mathematics support for better engagement may be to use students' approaches to studying as a guide to balance the elements.

Taking account of students' prior knowledge and experience of mathematical skills would be a good starting place for addressing the difficulties faced by the students. At the Robert Gordon University (RGU) all first year engineering and computing students from 1998 to 2006 were diagnosed for their mathematical skills and provided with a set of material to help improve ability in areas highlighted as weaknesses by the diagnostic test. A similar process was introduced to the engineering students at the University of Sheffield (UoS) in 2009. It needs to be noted that the mathematics diagnostic testing only evaluates prior knowledge and not cognitive potential with respect to learning mathematics in this research. Entwistle (2000) suggests redesigning the curriculum and teaching methods to help improve performance. This would involve activities and material to give students opportunities (maximise interest) to choose how and what they study, set a pace and workload that is more suited to students' learning pace. It would also involve assessment that rewards understanding and material that helps make connections between theory and practice.

Some of the ways misunderstanding of mathematics can be addressed are by providing definitions, diagrams and examples (Gill and Thompson 1995). Often the problem students have is not the one they come for help with, and being able to listen and pick up undeclared misunderstanding is a key skill for mathematics support tutors (Patel and Little 2006). To apply the search for meaning, teachers may be advised to turn course concepts into questions and use collaborative search for answers. Teachers are urged to turn their classrooms into rich environments for learning; to accommodate peripheral perception with posters, concept maps, and other adjuncts to their lessons placed around the room, and to involve students by organizing group work and other participatory activities (Gibbons, 2004 see Appendix 1)

Dewey (1897) believed if nine tenths of the energy at present directed towards making the child learn certain things were spent in seeing to it that the child was forming proper images, the work of instruction would be greatly facilitated. The key lies in developing the child's power of imagery and in seeing to it that he was continually forming definite, vivid, and growing images of the various subjects with which he comes in contact in his experience. To repress interest is to substitute the adult for the child, and so to weaken intellectual curiosity and alertness, to suppress initiative, and to deaden interest. To humour the interests is to substitute the transient for the permanent. The interest is always the sign of some power below; the important thing is to discover this power. To humour the interest is to fail to penetrate below the surface and its result is to substitute caprice and whim for genuine interest (Dewey 1897). The provision of mathematics support provides a partial solution to the need for individualised learning support for constructive learning (Epstein and Ryan 2002).

2.3 Emergence of mathematics support

The emergence of the provision of Mathematics Support has been driven by the need to address the issue of the declining mathematical skills of students entering undergraduate programmes with a numerate element (Lawson, Croft *et al. 2*003). One of the major factors leading to the need for a mathematics support facility (especially in the case of Post-92 universities) and contributing to the emergence of mathematics support facilities has been the growing diversity of the pre-entry qualifications and experiences with which students are entering HE (DFES 2003) due to recruitment demands placed on universities in the UK (Clarke 2003).

Extra-curricular mathematics support services in the UK have been set up since the early 1990's (Beveridge and Bhanot 1994) to help students gain a reasonable understanding of mathematics and statistics without which progression on their main programme of study becomes difficult and in some cases leads to increased attrition.

The most recent surveys of mathematics support provision in the UK indicated that more than 60% of the UK's HE Institutions (HEI's) provided some form of support (Beveridge 1997; Perkin and Croft 2004) in addition to the mathematics taught within the students' chosen programme of study. The type of support varies from institution to institution and can come in the form of: bridging courses, learning resources (paper and electronic), diagnostic testing and follow-up, drop-in centres, workshops, one-to-one support and peer assisted study support (Samuels and Patel 2010). Mathematics support centres are not only limited to the UK but are present also in other countries e.g. MacGillivray (2008) reports that most (33 out of 39) Universities in Australia provide some sort of mathematics support and similarly in the Republic of Ireland there are 13 (out of 26) tertiary mathematics support centres in place (Gill, O'Donoghue *et al.* 2008).

There are various models Institutes use to run a mathematics support facility (Lawson, Croft *et al.* 2003); some are run by dedicated members of staff who provide administrative and academic support, some use academic faculty staff to provide the tutoring and some use postgraduates to provide the tutoring.

There is evidence that students' mathematical ability affects progress on programmes of study that have a numerate element (Lawson, Croft *et al.* 2003). The Study Skills Centre (SSC) at RGU (Patel and Little 2006) and Mathematics Support Centre (MSC) at Maynooth in Ireland have evidence to suggest that mathematics support has a positive effect on the grades (Mac an Bhaird, Morgan *et al.* 2009) of the students who use these services. It seems to be particularly beneficial to students with weaker mathematics entry qualifications or diagnostic scores.

More than two-thirds of second and third year Arts students attended the MSC at Maynooth as opposed to about one-third of the second and third year Science students. This might be a result of the fact that the Arts students attending the MSC have chosen to study mathematics whereas for the Science students mathematics is a compulsory subject. The higher level of attendance by Arts students may reflect their interest in the subject. The difference was more pronounced for later years. In the case of the first year students, the at-risk students were more likely to attend than the students with stronger mathematical backgrounds, and seemed to be using the centre to improve their chances of passing the exam. In contrast, it was the strong students in second and third Arts who were more likely to attend and these students seemed not to be worried about failing, but were found to be using the centre to improve their chances of achieving first-class marks. This has similarities to the situation described in Pell & Croft (2008).

Mathematics support describes the provision of supplementary forms of teaching and resources for mathematics (including statistics) learning across institutions in addition to the main teaching provision. These can be a combination of a variety of methods (Patel 2004), some of which are listed here:

- *Individual tuition – enabling the addressing of specific needs*
- *Teaching logs – tutor maintained to enable reflective practice*
- *Diagnostic testing – enabling targeted support*
- *'Drop-in' facility – allowing for flexible and continuous study*
- *Workshops – making efficient use of limited resources*
- *Bridging courses – enabling levelling of ability for particular courses*
- *Learning resources: computer-assisted, video-assisted, and text-based self-study material - enhancing self-study*
- *Study groups – enhancing self-study and developing transferable skills.*
- *Peer-assisted support – helping both parties to develop skills*
- *Access to WebPages - links to external resources (e.g. MathCentre* (Mathcentre 2010)*, Mathtutor* (Mathtutor 2010)*, HELM* (HELM 2005)*).*

The structure of management and remit of mathematics support vary from institute to institute, some are centrally managed and university-wide whereas some are localised within a department or faculty for particular groups of students. Mathematics support is sometimes part of a wider support service where support is also available for statistics, writing and study skills.

This kind of support is resource intensive and as such, expensive but when considered in the context of its contribution to student retention (Patel 2004; Patel and Little 2006; Lee, Harrison *et al.* 2008; Samuels and Patel 2010; Croft 2000) it becomes worthwhile if not a necessary expense.

The requirements for mathematics support within UK HE are well documented (London Mathematical Society 1995; Smith 2004) and likely to increase in the future as the need for Mathematics Support increases with the weaker and/or increasingly diverse mathematical ability of the student intake. Although the mathematics support community is under threat due to the present economic climate (e.g. closure of the MSOR subject centres) it has responded positively and continues to develop and share approaches and resources.

2.4 Students attitudes to mathematics

Schoenfeld (1992) noted the importance students' *belief in mathematics* plays in learning mathematics when developing mathematical thinking. There have been studies by Liston and O'Donoghue (2009) and Parsons *et al* (2009) that have considered attitudes, belief, confidence and liking of mathematics in the mathematics support environment.

Confidence in and liking for mathematics were explored by Parsons *et al.* (2009) who described the process of improving students' mathematical confidence as 'a slow process, which cannot be achieved through quick remediation, unlike the method of ''filling in'' some gaps in mathematical knowledge'. Motivation and liking of mathematics proposed cycles of positive attitudes, effort and success for learning mathematics. High Overall Confidence in mathematics seemed to be a pre-requisite for independent learning in mathematics and Low Overall Confidence seemed to be causing a barrier to learning mathematics. Intervention helped raise confidence, and relationships were found between students' entry qualifications (Mathematics GCSE Grade and whether they had studied A-level mathematics), students' confidence in mathematics and their achievement in university engineering mathematics. Brown *et al* (2007) found that one of the main factors influencing students' attitudes to mathematics over the course of their studies was success at the subject with students with higher predicted grades stating attitudes such as *Confidence* and those with lower predicted grades claiming more negative attitudes towards the subject.

Liston and O'Donoghue's (2009) study analysed student attitudes in terms of beliefs about mathematics, mathematics self-concept and cohesive concepts of mathematics. The belief about mathematics (the student's view of the mathematical world) did not come up with reliable results and acknowledged the possibility of the results being attributed to prior experience of the students' mathematics learning while mathematics self-concept (students' self-perception/belief in their ability) showed a direct relationship with achievement. Cohesive conceptions of mathematics (how students focus on mathematics either as parts or as a whole) showed a relationship with students' approaches to studying.

Approaches to studying is one of the characteristics being explored in this research and the following section considers the theory underpinning students' learning styles and strategies to set the scene.

2.5 Mathematics related learning and teaching styles and strategies

Students' learning styles or approaches are used in this research to examine development and thus a broad review is provided to set the scene. The following range of styles currently being used will provide context. The author is not seeking to write another review, when a good one is already available from Entwistle (1988), but refers to learning styles and strategies and theories most related to students' mathematical development.

The distinction between learning styles and strategies is that styles are based on the individual's preferred methods, approach, manner and techniques for processing information, whilst strategies are the development skills defining schemes, approaches, policies, tactics, strategies, and line of attack an individual develops to learn and store information. Styles are more fixed characteristics and strategies are methods that may be used to cope with situations and tasks at hand and are thus more fluid (Riding and Cheema, 1991).

Learning styles research is useful in pointing out distinctions among learners and their modes of learning. Learning does not take place in isolation but takes place in context (Weinstein 1991) and builds on prior knowledge (Moran 1991), and as such research will incorporate this aspect of knowledge development with respect to mathematics support.

There are no right or wrong styles because they do not indicate ability but the personality trait of the individual (Entwistle 1988) which influences the way information is processed. An examination of the theories around styles in the context of learning again indicates the need for the engagement by the learner at a cognitive level.

Riding and Cheema (1991), state that the most well-known cognitive styles are, *Field Dependents* and *Field Independents*. The approach of the learner in these categories is either analytical or global. Witkin and Goodenough (1981) measure styles as a range, depth and speed of coverage; *Scanners* for whom the intensity of the attention given forms the range, *Levellers* and *Sharpener*s have a range based on how the memories are stored and extracted, *Reflectors* and *Impulsives* whose approach is based on the speed and adequacy with which they form alternative hypotheses with stimuli and concepts available.

Learning styles theories by Kolb (1984) and Honey and Mumford (1982) have resulted in the introduction of the experiential learning cycle. Briefly, experiential learning involves a cycle of learning through experiencing i.e. *Concrete Experience*, *Abstract Conceptualisation*, *Active Experimentation* and *Reflection* as illustrated in Figure 3.

There are styles with fewer dimensions such as Gregorc's (1984) whose four categories are similar to Kolb's except for the substitution of random and sequential groups for experiential and reflective groups. Kolb's (1984) model, though more complex, puts the learner in the scheme and gives a finer indication of dominance. Pask's (1976) model offers two dimensions; *Serialist* or *Holistic*, which lead to sequential and hierarchical organisation respectively.

The most influential theory of the 20th century in HE was developed by Dewey (1938) who observed that we are a learning species and our survival depends on the ability to adapt, rather than just reacting to fit in but instead proactively shaping/transforming our environment.

Though Kurt, Lewin and Lippitt's (1938) work is mainly related to learning and training it indicated their commitment to integrating scientific enquiry and social problem solving. Jean Piaget's (1955) contribution to the knowledge of experiential learning in the context of this research is related to the cognitive development (not an innate characteristic) of the tradition of experiential learning, i.e. how intelligence develops through the interaction between person and environment. The following section provides a brief review of some of the main learning theories.

2.5.1 Kolb's experiential learning cycle

The Kolb's (1984) cycle repeats in a progressive manner through:

- *Accommodation - Achieved through extensive transformation of apprehension*
- *Divergence - Achieved by reliance on apprehensive transformation by intention*
- *Convergence - Achieved through extensive transformation of comprehension*
- *Assimilation - Achieved by comprehensive transformation by intention*

Hence working with examples can lead to an evolutionary development of mathematical theory.

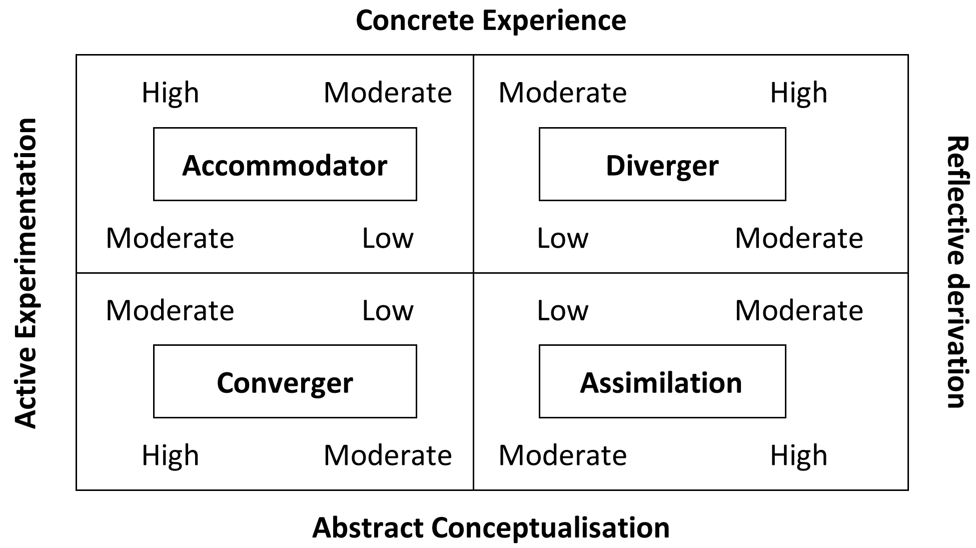


Figure 3 - Kolb's experiential learning model

Lewinean model of experiential learning

The Lewinean (1938) model takes the 'here and now' concrete personal experience to validate and test abstract concepts. Personal experience is important because it enables the learner to attach personal meaning to concepts which can be fed back into the process of generalisation and verification through reflection and testing. However, the cycle becomes ineffective when feedback is lacking.

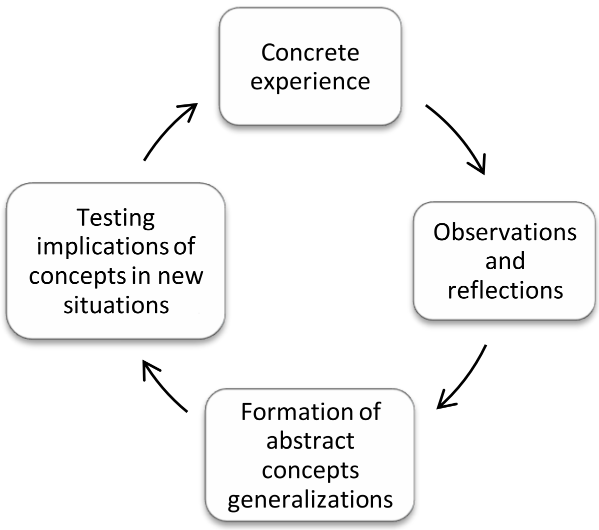
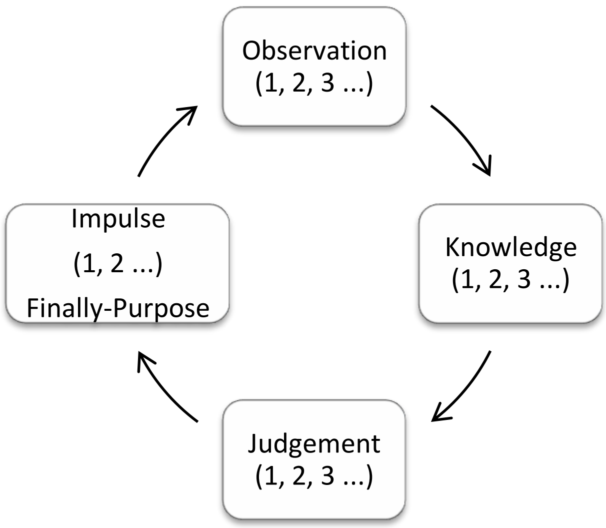


Figure 4 – Lewinean model of experiential learning

2.5.2 Dewey's incremental cycle

Process and structure of Dewey's (1938) theory presents four stages of adaptive learning models, concrete/abstract and active/reflection forming two dialectically opposed adaptive orientations with learning taking place when there is crossing over between the stages. How best students can be enabled to move between the stages is important.



Dewey proposed an incremental cycle which begins with blind impulse and application and reflection leading to mature purpose as the learner goes through numerous cycles before coming to a final purpose.

Figure 5 – Dewey's incremental cycle

2.5.3 Divergent and convergent thinking

Divergent thinking allows the generation of many different ideas about a topic in a short period of time by *brainstorming* – a key tool in brainstorming is "piggybacking," or using one idea to stimulate other ideas. Insight about the topic is gained by breaking the topic down. After this you can use *convergent thinking* to express ideas in a more organised and structured manner. *Mind-mapping* brainstormed ideas in a visual map or picture shows the relationships amongst these ideas. One starts with a central idea or topic, and then draws branches off the main topic which represent different parts or aspects of the main topic. This mapping requires both divergent and convergent thinking. By *free-writing*, a person will focus on one particular topic and write non-stop about it without stopping for proofreading or revising for a short period of time. Once a variety of thoughts have been generated the writing can be restructured. Finally, *Reflective Journals* are an effective way to capture ideas and insights that may occur spontaneously and at usual and unusual places.

Whereas *divergent thinking* involves tearing a topic apart to explore its various component parts, convergent thinking involves combining or joining different ideas together based on common elements. *Convergent thinking* means putting the different pieces of a topic back together in some organized, structured and understandable fashion to provide a solution. Research on the way the brain processes information demonstrates that people are able to efficiently absorb and retain up to seven main ideas at the same time, but no more. If there are more than seven ideas then grouping some together may help (Washington 2000). To learn mathematics and use it successfully it is important to be able to think convergently and divergently as there are usually a number of possibilities (processes) to consider when approaching a problem to solve.

2.5.4 Piaget's development model

Piaget's (1970) knowledge theory states that the empiricists concretise experience, grasping reality by the process of direct apprehension and the rationalists' abstract conceptualisation, grasping reality via the modelling process of abstract concepts is the means for the acquisition of knowledge. His model of learning and cognitive development revolves around learning and understanding rather than the learning process and spans over the learners age of 0-15, beginning with divergent to convergent cognition.

The main points of learning and cognitive development are the process of accommodation and assimilation. Accommodation of concepts and experiences *in the world* is used by the learner to change their own understanding of the world and the process of assimilation of events *from the world* is that of adding to and merging with the learners understanding. When assimilation dominates over accommodation we have play and when accommodation dominates assimilation we have imitation, imitation allowing the learner to think at a more abstract level which is beneficial to mathematical thinking.

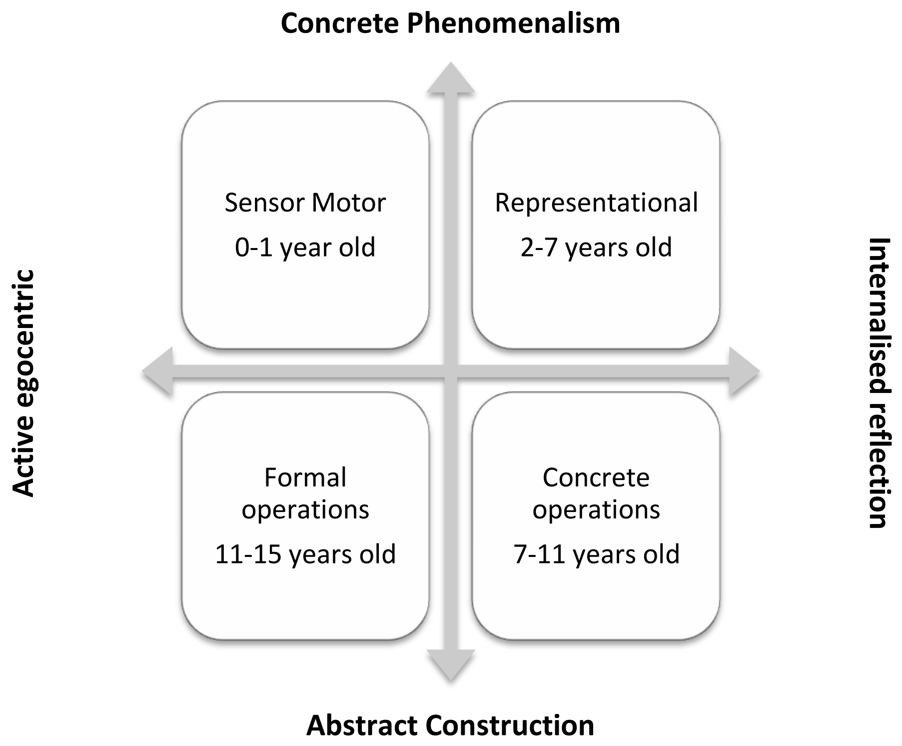


Figure 6 - Piaget's cognitive development model

This section provided a brief review of possible approaches for enabling mathematics learning more effectively. Actual examples of these are not tackled in this research which is more concerned with students' approaches to studying and how this effects their engagement with mathematics support.

2.6 Approaches to studying

In the early 1970s Marton and Säljö (1976) carried out research into the approaches of students to studying and this has been the chosen model in this research because there have been numerous studies on learning approaches and the use of *AtS* in HE (Entwistle and Peterson 2004).

Marton and Säljö (1976) identified two major approaches which they called deep and surface approaches to studying (*AtS*). The original instrument developed to measure these approaches was The *Approaches to Studies Inventory* (*ASI*) (Tait, Entwistle *et al.* 1998; Entwistle, Tait *et al.* 2000). There has been some discussion of how well this single dichotomy of approaches to studying suits studies examining students' learning especially as most of the studies do not take differences in disciplines into consideration (Ramsden 1997). In particular, as noted in the study by Beattie and co-authors (1997), it may not always be beneficial to use a deep approach for learning mathematics where learning requires practising of skills and processes. The instrument was developed further in the Approaches and Study Skills Inventory (ASSIST) to include the strategic approach (Entwistle and Ramsden 1983) to account for students using appropriate approaches for learning tasks.

Additionally, learning is complex and cannot be addressed using *AtS* alone without considering motivation, intention and context; some of these are considered in this research through the examination of attitudes of students towards mathematics.

2.6.1 Characteristics of deep and surface learning approaches

The characteristics of deep and surface learning are summarised in Table 2 below. The strategic approach is a combination of the two approaches dictated by need at the time, for instance working through and practising lots of examples (surface approach – fed by "surface teaching") in preparation for examinations and taking a more critical and meaningful deeper approach for course work.

	Deep Learning	**Surface Learning**
Definition:	Examining new facts and ideas critically, and tying them into existing cognitive structures and making numerous links between ideas.	Accepting new facts and ideas uncritically and attempting to store them as isolated, unconnected, items.
Characteristics	Looking for meaning.	Relying on rote learning.
	Focussing on the central argument or concepts needed to solve a problem.	Focussing on outwards signs and the formulae needed to solve a problem.
	Interacting actively.	Receiving information passively. Failing to distinguish principles from examples.
	Distinguishing between argument and evidence.	

	Making connections between different modules.	Treating parts of modules and programmes as separate.
	Relating new and previous knowledge.	Not recognising new material as building on previous work.
	Linking course content to real life.	Seeing course content simply as material to be learnt for the exam.
Encouraged by Students	Having an intrinsic curiosity in the subject.	Studying a degree for the qualification and not being interested in the subject.
	Being determined to do well and mentally engaging when doing academic work.	Not focussing on academic areas, but emphasising others (e.g. social, sport).
	Having the appropriate background knowledge for a sound foundation.	Lacking background knowledge and understanding necessary to understand material.
	Having time to pursue interests, through good time management.	Not enough time / too high a workload.
	Positive experience of education leading to confidence in ability to understand and succeed.	Cynical view of education, believing that factual recall is what is required.
		High anxiety.
Encouraged by Teachers	Showing personal interest in the subject.	Conveying disinterest or even a negative attitude to the material.
	Bringing out the structure of the subject.	Presenting material so that it can be perceived as a series of unrelated facts and ideas.
	Concentrating on and ensuring plenty of time for key concepts.	Allowing students to be passive.
	Confronting students' misconceptions. Engaging students in active learning.	Assessing for independent facts (short answer questions).
	Using assessments that require thought and require ideas to be used together.	Rushing to cover too much material.

	Relating new material to what students already know and understand.	Emphasizing coverage at the expense of depth.
	Allowing students to make mistakes without penalty and rewarding effort.	Creating undue anxiety or low expectations of success by discouraging feedback or excessive workload.
	Being consistent and fair in assessing declared intended learning outcomes, and hence establishing trust (see constructive alignment).	Having a short assessment cycle.

Table 2 - Compares the characteristics and factors that encourage deep and surface approaches to learning.

(Adapted from Biggs (1987), Entwistle (1988), Ramsden (1992) and Engineering Subject Centre (2000))

With the deep learning approach (transforming) students will seek to understand and make sense of processes and concepts (Marton and Säljö 1976). With this understanding they are able to choose and merge appropriate processes to find solutions; therefore unlike the surface learner they have a more acceptable workload. Strongest effects on learning come from the quality of teaching and the design of learning materials (Marton and Säljö 1976). Both closed and open assessment formats are suitable for these students although the open assessments offer more scope and a better platform for performance. The learning strategy they may adopt can be referred to as a *serialist strategy* if students acquire facts and information to understand and a *holist strategy* where students want to see the broad picture.

Students adopting a surface learning approach (reproducing) will learn by the acquisition of facts, processes and memorising as many different problems to apply in similar settings (Marton and Säljö 1976), leaving the individual with a heavy workload and restricted choices. Well-presented and logically structured teaching material or information is effective for this approach. Closed assessment procedures encourage surface approaches to revision i.e. memorising to reproduce content in the examination.

When students adopt a strategic learning approach (organising) they look for approaches that will allow them to achieve the highest possible grades. They will do this by strategically focusing on the forms of question anticipated and adopting well-organised and efficient study methods, often leading to the use of both surface and deep learning approaches (Entwistle 2003). This approach is strongly influenced by the teacher's requirements and reflects the intention of the students whether to reproduce, understand, interpret or assimilate information.

There is a consistent relationship between academic success and strategic approaches that avoid habitual use of surface learning, although interpretation has been complex (Entwistle 2003). There is also convincing evidence to show that where assessment requires reproduction of facts there is a tendency to take the surface approach while for questions requiring understanding, explanation and interpretation the deep approach is taken (Entwistle, Brown *et al. 1*994). Deep learning shows high achievement levels only in cases where assessment tests understanding. Unfortunately generally in first year UG studies showing correct information is the only requirement to progress to the next stage. A deep approach gives higher quality of learning and is crucial at final year of studies and of course students who have not developed this skill struggle. An approach to learning or studying can become habitual but is not a stable characteristic of the individual student (Entwistle 2003). The majority of the *AtS* studies have been in a social studies discipline (e.g. study skills). Case and Marshall (2004) considered *AtS* inEngineering and Science subjects and this is deemed appropriate literature for this research.

2.6.2 Procedural deep and procedural surface approaches to studying

Case and Marshall (2004) carried out studies with Engineering and Science students within the context of their courses. They intentionally went out to see if there were 'other' approaches that manifested themselves apart from the deep and surface approaches. The approaches they identified were: Procedural Deep, Algorithmic (referred to as Procedural Surface), Information-based and Conceptual. The last two approaches were noted to be very similar to Marton and Säljö's (1976) Surface and Deep Approaches (The Deep Approach can be defined as 'seeking meaning' whereas the Surface Approach is defined as 'reproducing content' (Prosser and Trigwell 1997; Entwistle and Peterson 2004). The strategic approach as stated earlier is a combination of the deep and surface approaches depending on the requirements of the particular context and student personal goals. The Procedural Deep and Algorithmic approaches will be looked into further in this research to better make use of knowledge of students' *AtS* in a learning mathematics context.

Every student has strengths that they can identify. Their strength may be relationships, athletics, artistic expression, character, assertiveness, languages, humour, organization, caring, construction, reliability or any among hundreds of others (Gibbons 2004). Similarly students have different *AtS*, learning styles, strengths and preferences in the way they take in and process information. To teach well, teachers need to be able to understand and operate adequately in all the learning styles. Teachers would also have to operate/teach to all the styles to some degree – otherwise the student's stress level will increase to a level where it will interfere with learning (Felder 1996). Thus aligning teaching methods to learning styles is briefly reviewed here.

2.7 Aligning of teaching methods to learning styles

Teaching styles and Instructional strategies are getting a higher profile with the emergence of alignment theories (Biggs 2003). At the same time there is a debate as to whether aligning teaching styles to learning styles is actually beneficial.

Despite alignment being a compelling idea there is a lack of empirical evidence to indicate its effectiveness.

Learning outcomes (traditional, empiricist, fixed consciousness ideas) by their nature can become limiting; *The learner is in a sense 'trapped', and finds it difficult to escape without learning what he or she is intended to learn* (Biggs 2003). They are based on fixed, built-in and unchanging ideas, providing only a historical record of activity carried out, not knowledge of the future whereas the adaptation processes (experiential outcomes, ideas not fixed and capable of being changed) through interaction with the environment leads to emergent learning and is more desired than simply the fulfilment of learning outcomes.

Theories of learning range from the form of systematic programmed study of Skinner (Epstein 1982) in the 1950's to a move towards a psychological and clinical description by Piaget (1970) and, more recently, to constructivism. The constructivist learning paradigm transforms the 'teacher-directed learning' to 'student-directed learning' (Gibbons 2004). According to Gibbons these types of learning are not mutually exclusive and learners and teachers can operate within a continuous spectrum (see Figure 7) within these poles. Possible stages have been identified as:

- *Incidental Self-Directed Learning where learning is mainly teacher led with a few student-directed learning episodes.*
- *Teaching Students to Think Independently where students are encouraged to find personal meaning*
- *Self-Managed Learning where students have to carry out learning by completing guides – working through self-help material*
- *Self-Planned Learning where students have to design their own activities to ensure that the final outcomes belong to the learners.*
- *Self-Directed Learning where the students choose the outcomes and design activities to achieve them and pursue them independently.*

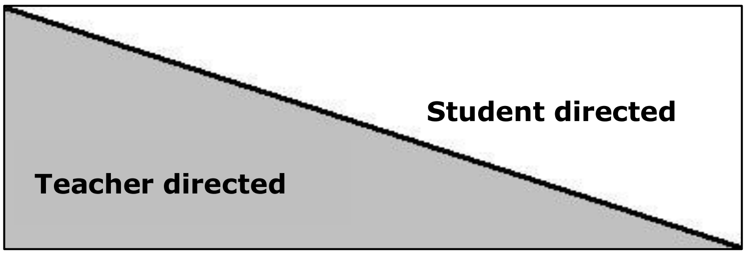


Figure 7 - Teacher/student directed learning

A means of measuring learning needs to be explored and stated here for later use in the evaluation stage. Marton's (1996) work on learning by reproducing or transforming (Entwistle, Brown *et al. 1*994) provides a basis for measuring learning.

Dewey (1938) states that true education comes through the stimulation of the child's powers by the demands of the social situations in which he finds himself; again the emphasis is on the learner to situate their understanding and knowledge. Social meaning of knowledge is necessary for the transformation because the educational process has two sides; one psychological and the other sociological, both being organically related. More often than not, unless a conscious effort is made, the education process is incompletely delivered with concentration on the psychological mainly and it is only by chance the learner may come across an activity that allows sociological understanding, making the learning process haphazard and deep learning less likely to occur. A fruitful approach would be to consider the learner's psychological insight, capacities, interests, and habits and translate them in terms of their social equivalents (Dewey 1938). This way learning becomes a process of learning and not just prescriptive education which does not necessarily prepare the learner for living. Additionally, prescriptive learning is not easily remembered and recalled to reapply in similar cases. Life skills are normally required to be used and reused in a variety of situations and if learning through experience is provided the students will be able to incorporate it within their store of experiences and recall for application in different situations.

The report of the Learning Environments and Technology Working Group led by MacFarlane (1999, Section 3.3) to the Committee of Scottish

University Principals identified a series of functions of teaching which support student learning:

- *Orienting – setting the scene and explaining what is required*
- *Motivating – pointing up relevance, evoking and sustaining interest*
- *Presenting – introducing new knowledge within a clear, supportive structure*
- *Clarifying – explaining with examples and providing remedial support*
- *Elaborating – introducing additional material to develop more detailed knowledge*
- *Consolidating – providing opportunities to develop and test personal understanding*
- *Confirming – ensuring the adequacy of the knowledge and understanding reached.*

Transferable skills; problem-solving, Initiative and efficiency, Interactional skills and communication skills have been identified by the Enterprise Initiative (Entwistle, Brown *et al. 1*994) and added to the original list to meet today's education community needs more fully.

Describing students as either deep, surface or strategic learners is overly simplistic and cannot be definitive because people are more complex than this categorising suggests. Also the use of the words 'deep', 'surface' and 'strategic' may seem inherently judgmental (Shales and Trigwell 2004) but in reality these are merely words which describe the approaches of individuals not the individuals themselves. However, the use of the strategic approach would allow for more development and change. The strategic approach will be the preferred approach because it allows switching between the first two approaches and the drawbacks of labelling students with an approach can be minimised.

Students are aware of the need for 'real understanding' and in some cases what is involved in achieving it but the need to succeed in assessments surpasses the need for deep learning. Provision of study skills in aiding understanding would resolve part of the problem but teachers have to make a conscious effort in the production of course material to enable the deep approach. This would need to include careful assessment setting, whereby it is understanding that is being assessed and not just the ability to regurgitate information. There is also a tension that staff have to balance that of passing students.

However, with the increasing diversity of the undergraduate intake in UK HE, research into approaches to studying is becoming increasingly important in order to enable a more personalised and effective opportunity for learning.

Cronbach and Snow (1977) showed that alignment can be detrimental as the students use their preferred learning styles because of familiarity and the ease of use it offers. This leads to limited learning because they do not select the ideal learning strategy for the teaching style being presented and will not go on to develop other learning strategies.

In practical terms alignment is a daunting task because of the wide range and non-definitive sets of learning styles and generally courses are based on the learning styles of the course developers not the learners. Unfortunately due to a review by Cohen and Associates (cited in Davidson 1990) the teaching of alignment of teaching styles to learning styles was dropped from the teacher training curriculum because it was not noted as beneficial, and this is more likely to halt determined research in the area. According to Davidson (1990) matching teaching styles to learning is not practical because there are too many learning styles and the list is not definitive. A majority of teachers teach using their own preferred Learning Styles rather than the students'. One of the more traditional instructional methods in the Classroom is lecturing. Instructors may need to add question-and-answers sessions, guided discussion or hands-on activities for variety. This would allow students to take responsibility for their own learning.

In a classroom, alignment is not practical since many learning styles will be present but in a mathematics support environment where one-to-one tutoring takes place there is a choice, though many of the students will want to adopt surface approach in order to passing coming examinations rather than the deep approach which would put them in better stead in the longer term.

Informing students of their own Learning Styles will allow them to seek and develop cognitive skills and thus increase control of their learning situation. They will be able to determine whether certain Teaching Styles are suitable for their Learning Styles and if not, to adapt or compensate for them. Instructors need to broaden their awareness and accept differences among people. People tend to be egocentric about how they learn and retain and assume that everyone learns as they do.

In conclusion, matching teaching styles to learning styles does not necessarily improve performance. No one has proven it yet, although awareness of learning styles is necessary to describe the cognitive diversity of students. Therefore in this research aligning teaching styles to learning styles is not tackled but learning styles are reviewed because of links to approaches to studying which are considered in this study.

3 Methodology

This chapter describes the action research methodology (Cohen, Manion *et al.* 2000) employed in this research; it illustrates the formation of the research questions and the experimental design for measuring the effectiveness of mathematics support on students' mathematical performance. The students' mathematical ability at the start of their programme of study was correlated against their performance in mathematics related modules at the end of their first year of study. Mathematical ability at the beginning of the programme here is limited to measures of mathematics entry qualification and basic mathematics diagnostic test results. During the year students will have engaged with the general learning and teaching within their main programmes of study and some will have made use of additional mathematics support.

3.1 Action research methodology

Action research methodology has been used to capture the author's experience of the provision of mathematics support, reflecting on the effects of support on students' performance and the practical need to improve provision for sustainability. The development of mathematics support at RGU (Patel 1996; Patel 1998) took place through review of good practice and implementation of appropriate methods for the Institute. The practice was evaluated on an ongoing basis with the sharing of ideas and methods with the mathematics support community and used to refine the Institute's own practice. Reflecting on the effectiveness of the support (initially driven by the need to justify the provision of mathematics support) had led to the need for a more systemic approach to demonstrating usefulness of mathematics support. This cyclic reflective approach as illustrated in Figure 8 has now been adopted in the author's new role at the UoS.

Figure 8 – Action research cycle

As stated earlier, practice of mathematics support at RGU was investigated to evaluate for effectiveness. This led to implementation of good practice and thinking of ways of improving effectiveness even if this simply meant better engagement with mathematics support by students. Evaluation of the new practice and methods helped staff to reflect on and refine practice. This implementation of the action research cycle (Whitehead 2008) underpins the research.

The stages of the action research methodology and the corresponding activities for this research are summarised in table 3 below.

Action research	**Activities**
Review of current practice	Examine usage data and note trends and performance of *MSU*[3] and *Non-MSU*
Aspect to investigate	Identify characteristics of *MSU* students, compare performance, again factoring out characteristics found to reduce possible integral bias.
Way forward	Examine *AtS* as one of the characteristics to differentiate between student *types.*
Try out way forward	Develop *AtS* instrument for use in mathematics support setting and trial.

[3] Mathematics Support Usage

Evaluate way forward	Evaluate performance by *MSU* and *Non-MSU,* factoring out characteristics i.e. *AtS*, using a regression model.
Refine investigation	Refine *AtS* instrument and regression model.

Table 3 – Actions research stages

3.2 Ethics approval

This research has been approved under the Medium to High Risk Research Ethics category by Coventry University. Additionally, the *AtS* survey was approved by the UoS for service review purposes.

3.3 Reviewing current mathematics support practice

3.3.1 Mathematics support

Only the learning and teaching methods and techniques for mathematics support are summarised in this study. The main activities that sum up mathematics support at RGU and UoS are listed below. Often students do not use just one method but a combination of methods to suit their needs. Services include the following:

- *One-to-one tuition*
- *Diagnostic testing and follow-up*
- *Workshops*
- *Exam revision preparation*
- *Online and paper-based self-help resources*
- *Self-help groups*
- *Teaching logs*

Generally mathematics support exists to help students improve on their mathematics skills without which they could be at risk of not progressing to the next stage of their studies. In addition, though no specific incentive for more able students was provided, feedback from the centre tutors indicated that those students who already had good mathematical skills were making use of the service in an attempt to improve further on their performance. This is also confirmed in studies by Perkin and Croft (2004), Patel and Little (2006) and Pell and Croft (2008).

It was felt adequate mathematics support provision was possible when course pre-entry requirements are identified and matched to students' ability in these areas followed by targeted support. Hence the use of a mathematics diagnostic test was part of the practice at RGU and UoS.

3.3.2 Basic mathematics diagnostic testing

Diagnostic testing of new undergraduates has become common place in HE (Lawson, Halpin *et al. 2*001) because of the wide range of mathematical skills base with which students are entering their programmes of study and lecturers' need for awareness of these skills base early enough to ensure progress is not hindered due to poor preparedness (Lawson, Halpin *et al. 2*001). This is particularly true of students on engineering courses for whom a good standard and understanding of mathematics is crucial for successful completion. This identification process is not straightforward since many students will exhibit the same symptoms but actual prescription to address the symptoms requires correct diagnosis and not simple identification.

The basic maths diagnostic test (*BMDT)* used at RGU is based on one developed by Appleby (1996) with a few new questions added. The original full test contained 90 questions (Appendix 2), with a pass mark of 50% and students scoring 30% or less were considered at risk of struggling and thus strongly advised to get help. The length was not ideal as it was too long and time consuming for staff and students, but the questions were deemed necessary by the author in order to cover pre-requisite skills required by the courses students were planning to study on. The test questions were categorised within the following topics: Numeracy, Algebra, Miscellaneous, Area & Volume, Graphs, Equations, Powers, Statistics, Trigonometry and Calculus. The total number of questions in the *BMDT* at UoS is 40 (Appendix 4), and students are expected to score highly, above 75%, as the questions are testing only for the *fundamental mathematics* that lecturers assume students will be proficient in. The categories the questions have been placed in are: Number Skills, Notation, Linear Equations, Quadratic Equations, Algebra, Fractions, Factorisation, Indices, Logarithms, Complex Numbers, Differentiation and Integration. The RGU and UoS tests were administrated online to the new intake for engineering and computing courses at the beginning of each academic year, in week 2 or 3 at RGU and week 0 (Intro-week) at UoS.

All the UoS students (totalling 614) who sat the *BMDT* during the induction week in 2009-10 were additionally presented with the ASSIST+ questionnaire via email and again with a paper version of the questionnaire when they came to the Mathematics and Statistics Help (MASH) Centre to pick up the diagnostic test paper version of their results and a memory stick with HELM mathematics resources (HELM 2005) and mathematics study skills worksheets (Deane *et al.* 2009). Of the 614 students who carried out the *BMDT* only 217 (35.3%) came to the Centre to pick up their results and they were asked to complete the ASSIST+ questionnaire with the incentive of being entered into the draw for one of a hundred basic scientific calculators donated by sigma CETL. The students were asked to pick up their results from the centre to allow for exposure to the services offered by the Centre because one of the issues identified in a survey of students (see Appendix 9, Q2 and Q4) regarding the services provided at the mathematics support centre, was the lack of knowledge of the mathematics support services available (Patel and Rossiter 2009).

Record keeping and collection of relevant information on students using mathematics support became part of the support provision as did observing performance of students. The positivist approach (Cohen, Manion *et al.* 2000) is used for analysing effects of mathematics entry qualifications (*MEQ*), mathematics support usage (*MSU*) or non-usage (*Non-MSU*) on module results to test the theory that good *MEQ's* (sufficient ability in mathematics) and mathematics support leads to better performance. The effects of students' characteristics (*Age-group*, *Attitudes* and *AtS*) and mathematics support intervention are also analysed for effectiveness and strength as performance predictors.

Students' mathematics skills base was measured using their *MEQ* and the results of a basic mathematics diagnostic test (*BMDT)* and performance on relevant modules provided the measure of mathematical skills base at the end of the year. Intervention factors apart from the mainstream teaching are related to mathematics support.

3.4 Aspects for investigation

3.4.1 Approaches to studying instrument

A questionnaire to elicit a multiple component construct (Tait, Entwistle *et al. 1*998) of students' approaches to studying is described here and related to the current research literature into approaches to studying in the context of mathematics education.

The original inventory was specifically written with HE in mind (Coffield, Moseley *et al. 2*004) and contains 44 questions, to identify different approaches to studying and 8 to identify students' teaching styles preference. It is based on a five point Likert scale. The main reason for using this questionnaire is that it has already been used in numerous studies (Entwistle, Tait *et al. 2*000), one study with four British universities, one with a Scottish technological university and one South African university. Additionally, in a study of 139 2nd year Business Analysis students, Enjelvin and Sutton (2004) found the ASSIST questionnaire to be reliable giving more strength to its value.

There has been some discussion of the appropriateness of assigning Deep and Surface approaches to studying to students without considering discipline or context (Biggs 1993). Case and Marshall (2004) have carried out studies with Engineering and Science students within a course context. The unusual thing about their studies was that they did not restrict their approaches to Deep or Surface, remaining open to discover 'other' approaches that may manifest. Case and Marshall (2004) carried out two studies separately in engineering course settings and used a broad construct of 'approaches to learning', assuming this to have utility and validity with specific approaches present as identified from the data using grounded theory (Cohen, Manion *et al. 2*000). Validity of their studies is strengthened further by the use of the Drew, Bailey *et al (*2002) and Booth's (Booth 1992) method. Cohen had also introduced context for significance. Despite the differences in the location and methods of Case and Marshall's (2004) research the comparison is useful because the authors state the difference and acknowledge the non-comparable parts. Their approach is slightly different to Drew *et al* (2002) and Booth (1992) in that they did not restrict their study to just approaches to task based learning but also considered approaches to a course in general. The result of the Case and Marshall (2004) study was the identification of *Procedural Deep and Algorithmic (referred to as Procedural Surface) as* possible new approaches in which students develop progressively by working through and memorising processes. .

The questionnaire used for this study is an augmented version of the Approaches and Study Skills Inventory for Students (ASSIST) questionnaire (Tait, Entwistle *et al.* 1998). Where the original ASI (Entwistle and Ramsden 1983) contained seeking meaning and ideas subscales, in ASSIST these are put into the Deep learning approach. Table 69 and Appendix 10 provide the questions making up ASSIST + (pronounced ASSIST plus), highlighted questions are new and added to the original ASSIST questionnaire and are introduced by the author to identify procedural deep and procedural surface learning as described by Case and Marshall (2004). Appendix 11 gives a breakdown of the questions scales and subscales. The original questions were drawn up by Tait, Entwistle *et al.* (1998) and the new Procedural Deep and Surface subscales are highlighted in Table 69.

Questions were developed (as shown in Table 4) to identify Procedural Deep and Procedural Surface approaches in order to investigate if science students were better described through these approaches rather than by only the original deep, surface or strategic approaches. Table 5 indicates the placing of these new approaches within the original *AtS* scales (Case and Marshall 2004). The reasoning behind this introduction of new approaches was to better identify the *AtS* of students in a science discipline. Generally it is felt the deep approach is preferred to the surface approach in science students because of its longer lasting learning development effect. Certain types of memorising are considered a surface approach trait but in a study by Marton, Dall'alba *et al.* (1996) students were shown to learn by memorising but the memorising led to deeper understanding of the subject; hence memorising in this case would be better captured if shown to be able to lead to, if not belong within, a deep approach. This type of memorising has been described as meaningful memorising (Au and Entwistle 1999). In practical terms the author is assuming that to be able to use and apply mathematics, certain processes need to be learnt, memorised and practised before students can fluently manipulate the processes in a variety of problems and settings. So there is room to explore the need for using the surface approach for learning processes in mathematics, but instead of the surface approach we will be looking at how using procedural deep and procedural surface approach categories may be a better placing for students in a science discipline.

	Questions to identify procedural deep and surface approaches 5 = Agree, 4 = Agree somewhat, 3 = Neither agree nor disagree, 2 = Disagree somewhat, 1 = Disagree
PD	I enjoy developing formulae when problem solving
PD	I like seeing the relationship between different formulae
PD	I like to develop new steps in a procedure
PD	I like to make use of processes I've learnt
PS	I am good at memorising methods and processes
PS	I prefer working with fully worked out examples in lectures
PS	I like trying out lots of examples
PS	I am good at using a formulae sheet

Table 4 – Additional questions to identify procedural deep (PD) and procedural surface (PS) approaches to studying

	INTENTION	
STRATEGY	***Passing the assessment***	***Understanding***
Memorising	Surface approach	
Problem solving	Procedural surface approach	Procedural deep approach
Understanding concepts		Deep approach

Table 5 - Intention and strategy for approaches to studying – adapted from Case and Marshall (2004)

Table 6 provides the main characteristics in terms of strategy and intention of the approaches.

Approach to Studying	Strategy	Main Intention	Sub-Scale
Deep Approach	To transform knowledge and integrate ideas	To understand and integrate to prior knowledge	Relating Ideas
			Seeking Meaning
			Use of Evidence
Surface Approach	To reproduce information	To simply reproduce contents	Lack of Purpose
			Syllabus- Boundness
			Unrelated Meaning
Strategic Approach	To combine approaches to suit need	To pass assessments	Alertness to Assessment Demands
			Organised Studying
			Time Management
Procedural Deep Approach	To relate knowledge to other knowledge	To understand through problem solving procedures	Relating Processes
Procedural Surface Approach	To memorise processes	To pass assessments	Memorising Processes

Table 6 – Characteristics and sub-scales within AtS of the ASSIST+ questionnaire - including new sub-scales based on Case and Marshall (2004)

Mathematics requires the ability to problem solve and for engineering undergraduates especially as this can be attached to some form of assessment. In the Case and Marshall's (2004) Procedural approaches study it was seen that students were to varying extents influenced by the need to pass. But within this need was also a difference between the procedural deep and procedural surface learners; in the former there was an intention to understand, if not right away then at a later time when working through problems (different from the original deep approach (Tait, Entwistle *et al*. 1998), this is less sophisticated); in the latter (procedural surface) the students were drawn towards an algorithmic approach where they work through problems to become better at using processes with no serious intention to gain understanding (again different from the original surface approach, this being more sophisticated). Based on these concepts the procedural approaches (table 4) are used to see if they sit within the deep and surface approaches (Case and Marshall 2004).

For this research new procedural questions were introduced to the ASSIST questionnaire (forming the new ASSIST+) to examine the strength of loadings to *AtS* scales Deep and Surface of the new Procedural Deep and Procedural Surface subscales using factor analysis as performed in the study by Rodríguez and Cano (2007). ASSIST+ is undertaken by a cohort within the new UoS intake.

The ASSIST Shorter version (ETL 2005), with the addition of the questions developed for the identification of the procedural deep and procedural surface approaches was used at the end of semester 1 with the cohort who completed the original survey. Included also were the questions to identify *Attitudes* to mathematics (section 3.4.2). A further 17 results were obtained from students from second and above years who have made use of mathematics support, these results having been used to determine whether the desired change (for instance increase in the Deep approach score) in *AtS* scores was actually taking place.

The pre and post intervention results of the first year engineering students' *AtS* will allow for analysis of changes in *AtS* and the effect of mathematics support on the *AtS* scores. It is assumed some will make use of the mathematics support available and some will not which will provide a means of comparison.

3.4.2 Attitudes towards mathematics

To capture the students' attitudes on perceived ability in mathematics, liking for mathematics and past experience the author has used the closed questions on Attitudes 1, 2 and 3 below, originally used with the RGU cohort during diagnostic testing.

Attitude 1 - Which best describes your ability in mathematics?

Excellent = 5, Good = 4, Fair = 3, Bad = 2, Very Bad = 1

Attitude 2 - Which best describes your feelings for mathematics?

Find it interesting = 5, Find it enjoyable = 4, Indifferent = 3, Don't find it enjoyable = 2, Don't find it interesting = 1

Attitude 3 - Which best describes your past experience of mathematics?

Excellent = 5, Good = 4, Fair = 3, Bad = 2, Very Bad = 1

The studies by Liston and O' Donoghue (2009) and Parsons, Croft *et al.* (2009) have analysed students' attitudes in terms of beliefs about mathematics, mathematical self-concept, confidence in mathematics, liking for mathematics and motivation. However, for consistency the original questions used to rate *Attitudes* at RGU were not substituted with these as a comparison between the two institutes was at the time thought to be useful. It has since been felt that the differentiation between *interesting* and *enjoyable* in the 'Liking of Mathematics' question was too subjective and has weakened the survey.

3.5 Research design

Issues for research were identification using the observations based on the analysis of the RGU dataset, including the author's experience, and on the mathematics support community literature review. The provision of mathematics support has improved students' performance as shown in a prior study by the author (Patel and

Little, 2006) where more students (4%) who had used mathematics support passed their modules than students who did not use mathematics support (see Table 7).

Table 7 has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Table 7 – Percentages of module passes with and without mathematics support: extract from Patel and Little (2006) p133

Students show a preference for some mathematics support methods more than others (Lawson *et al.* 2003), one-to-one being most popular, others being workshops, use of handouts, online resources, diagnostic testing and follow-up and audio and video resources.

Inference for this research is that some forms of mathematics support are preferred by and work better for some individuals because of their preferred studying approaches (Biggs 2003). Although Biggs' research is related to mainstream teaching, the principles of alignment can be translated to a mathematics support environment. Making appropriate methods (not just one-to-one support which is resource intensive) available to individual students will provide a more cost effective means of providing mathematics support in the longer term.

The method for examining the effects of mathematics support comprised studying students' performance on modules against *AtS*, *BMDT* percentage and *MEQ*. This enabled the identification of trends and correlations between student profile factors (*BMDT*, *MEQ, Attitudes* and *AtS*) making up the independent variables, the dependent variable being mathematics module results with mathematics support as the intervention.

The justification for the time and resources put into this study is the current concern regarding adequacy of mathematical ability for study in many science discipline undergraduates (Hawkes and Savage 2000) and the need to address this in a sustainable way.

> *"Properly resourced tutoring systems help individual students to identify the extra support and facilities they can use to improve their chances of success. Institutions often offer pre-entry courses and learning support opportunities, but many institutions find it difficult to get students to take up services that would help them to 'stay the course' and succeed. This can be because students and academic staff may regard the services as being there to fill a 'deficit' in a student's ability, but* ***institutions can increase take-up by promoting these services as positive options to take to improve the prospects of a good degree****."* National Audit Office (2007 p11).

As stated earlier in Chapters 1 and 2 there are numerous research studies that have sought to measure the effectiveness of mathematics support (Lawson, Halpin *et al*. 2001; Parsons 2005; Patel and Little 2006; Croft 2009; Mac an Bhaird, Morgan *et al*. 2009). The author's research will add to this body of research. The research design is provided here and it is assumed that mathematics support has a positive effective on students' mathematics performance as any additional input is likely to contribute to better results. The contribution of the research is the design of a model for measuring effectiveness of mathematics support and recommendations for presenting effective mathematics support in a form that suits students' *AtS* scores and *Attitudes,* in this way optimising the provision of mathematics support.

3.5.1 Scope and limitations of the research

The two Institutes in this research are Post-92 and Russell Group Universities and as such naturally attract students with different profiles. Therefore, though there are some similarities in the mathematics support usage and progression for the two, a direct comparison would be inappropriate and as such was not carried out.

The data for RGU was collected in and up to 2006 and there has not been opportunity to collect additional and missing data, which has led to an element of uncertainty concerning the comparison between RGU and UoS regarding the trends of students in terms of their entry qualifications (section 5.1.2). However it was decided not to discard the dataset completely because of this uncertainty as it was felt that data collected over a long period 1998-2006 would provide some useful trends.

A part of this collection was on students' attitudes towards mathematics which over the years has provide a sample size of round 600 responses from RGU whereas from UoS we only have 37 responses collected in one year. The high numbers of responses from RGU have been used to provide an explorative study on attitudes and the survey questions themselves only.

The approach of the analysis for these responses has been carried out by converting the Likert scales to numerical data which introduces limitations as the scales which are ordinal though sequential are not necessarily equidistant as the numerical conversion data implies. However to limit the weakness of the analysis the intervals have been truncated into 2 sequential groups scales 5 and 4 have been combined into one strong positive selection with 1, 2 and 3 combined into one non-positive selection (Allen and Seaman 2007). This truncation of the intervals has been used in the analysis for the attitudes towards mathematics and these groups have then been used only to explore relationships between attitudes towards mathematics and module performance. A deeper analysis has not been undertaken because of weakness in the survey questions for the Liking for mathematics attitudes noted in section 3.4.2. There is concern about the meaning and interpretation by the respondents of the survey of the words 'Interesting' and 'enjoyable' being subjective. The result of this explorative study has led to recommendations for further study in the area (see chapter 7) which would include refining the attitudes' questions and carrying out reliability tests on the questions followed by non-parametric tests.

Measures of changes in students' mathematical ability has been restricted firstly to mathematical skills only because this research is not a psychological study measuring learning ability and secondly, to crude measures of changes in mathematical skills i.e. measures of skills before and after a period of study. Changes in skills have been reduced to changes in the means of the before and after scores to represent learning development or gain.

The same test at entry and exit should have been used but this was not practical and it is not certain that the same mathematics test delivered at the start and end of a period would really show development in skills. The post-test needs to have the same level of difficulty but after a semester of participating in learning activities the results of the post-test may just be measuring the ability to take the test more successfully and not actual change in skills. Additionally the testing processing itself may have an effect on the result. Therefore independent samples t-tests have been used for the *BMDT* and module marks to examine the value added by mathematics support. The classic pre-post-test analysis is not possible as this would require the use of exactly the same test before and after intervention but using the same test may also produce skewed results because of familiarity. For practicality it is possible to use tests of the same kind as pre and post-tests. However, BMDT and module marks do not lend themselves very well to this approach as they are not similar. Individual questions on the diagnostic test are designed to be answered correctly or incorrectly with no partial credit. It is anticipated that highly qualified students will score very highly on the test whilst poorly prepared students will record very low scores. It is fully expected that the marks will not be normally distributed. On the other hand, the end of module exam has questions which do award partial credit and it is expected that even struggling students will be able to score a few marks from the "easier" early parts of the questions and it is also expected that there will be only a handful of very high marks. The marks are likely to be much closer to a normal distribution and the standard deviation would be expected to be considerably smaller than for the diagnostic test. In other words, with no intervention one would expect the *BMDT* marks to be squeezed with (probably) a reduction in the mean but definitely a large drop in the standard deviation. These effects have an impact on these measures therefore only comparison of the differences in the means for BMDT and module marks has taken place (Section 5.2).

A limitation in relation to the *AtS* analysis was that score means were used to measure changes in students' *AtS*, this approach simply averages out the scores and takes no account of the extremes that would cancel out and lead to loss of valuable information. The approach to the analysis used is based on the numerous studies (Entwistle and Peterson 2004) using numerical values for the responses to the survey. Statistically this approach is not accepted by the pure statisticians but as a study in mathematics education and because of the use of this approach in the other *AtS* studies it has been deemed acceptable. The finding of this limited *AtS* analysis has thrown up interesting results such as the increase in surface approach scores which needs confirming and is recommended for thorough further research. The *AtS* sample size (122 at pre-intervention 37 at post-intervention) is smaller than the recommended 150 (Tabachnik and Fidell 1996). Therefore although the analysis is not deemed as robust as desired it is a useful starting point for further research in a mathematics support setting.

A student's mathematical ability is not easy to quantify but mathematical skills can be measured using scores for *MEQs*, *BMDT* and Module results and therefore have been used as a substitute. Mathematical skills at entry were measured using *MEQs* and *BMDT* and performance on a mathematics module for mathematical skills at exit. Additionally any difference in strength of correlation between ability at entry and exit for *MSU* and *Non-MSU* implies only a relationship and not causality.

3.5.2 Hypothesis

Mathematics support has a positive effect on students' performance when prior mathematics entry qualifications and any bias introduced by student's characteristics are factored out.

3.5.3 Research questions

1. How does the performance on mathematics modules compare for MSU students with certain entry mathematics qualifications and mathematics diagnostic test results with their peers?
2. How does the performance on mathematics modules compare for MSU students with certain levels of engagement with mathematics support with their peers?
3. How does the performance on mathematics modules compare for MSU students with certain attitudes towards mathematics with their peers?
4. How does the performance on mathematics modules compare for MSU students with certain approaches to studying with their peers?
5. How does the approaches to studying scores of MSU students change after a semester of teaching in comparison to peers?

The mathematics entry qualifications and the mathematics diagnostic test results give an indication of students' mathematical skills base at the start of the programme of study. The inclusion of the approaches to studying scores takes into account some of the bias integral to the use of intervention that is accessed voluntarily. The assumption that a certain type of student (i.e. 'at risk' or highly motivated) will make use of mathematics support and comparison of results of *MSU* and *Non-MSU* students with like *AtS* scores provides some measure of reliability (total reliability is only possible when all possible factors can be taken into account).

3.6 Analysis overview

The following statistical tests will be used to analyse the data and produce the algorithms for the development of a model for measuring and improving mathematics support.

3.6.1 Statistical analysis

1. Independent samples t-tests are used to measure the effectiveness of mathematics support (Pallant 2005).
2. Exploratory and confirmatory factor analysis to examine the strength of ASSIST+ questions in this sample and the Cronbach Alpha scales to measure reliability of each of the sub-scales (Rodriguez and Cano 2006, Liston and O'Donoghue 2009).
3. Use of multivariate ANOVA to test for differences in results of *MSU* and *Non-MSU* students (Pallant 2005, Rodriguez and Cano 2006).
4. Use of multiple regression analysis to work out best predictors (*MEQ*, *BMDT*, *AtS*, *MSU* visits) for module results.
5. Paired t-tests to test the effect on mathematics support on *AtS*.

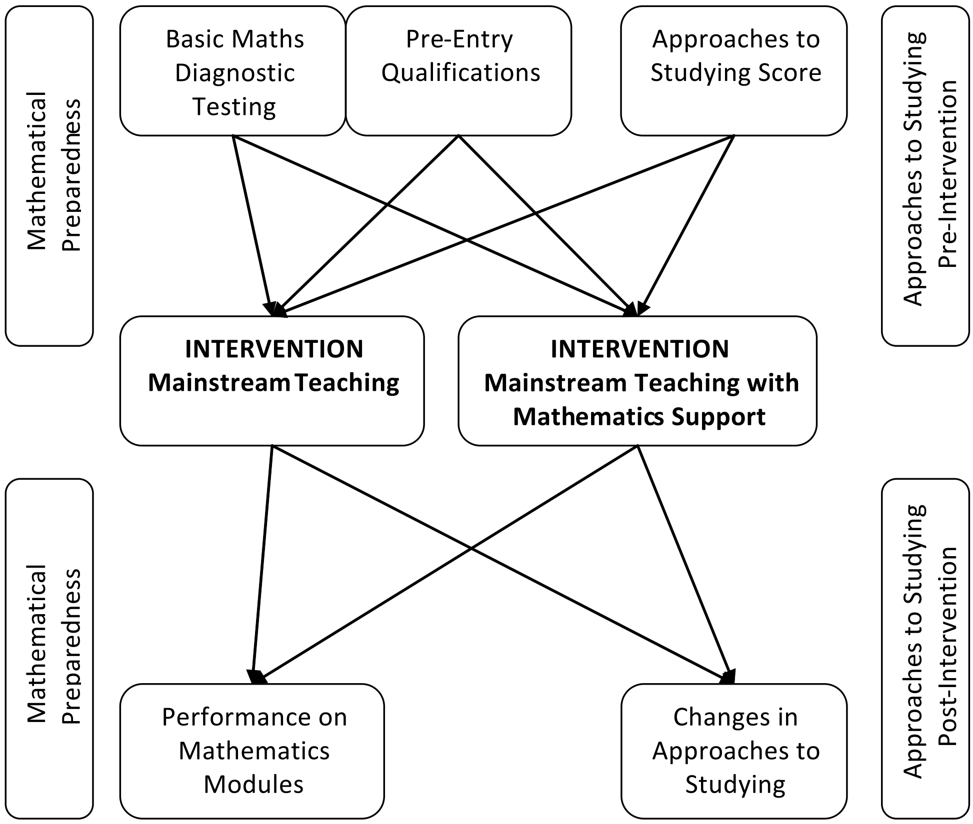


Figure 9 – Research design overview

3.6.2 Analysis stage 1 – Initial evaluation of mathematics support

The initial analysis provides a background for measuring the effectiveness of mathematics support on module results using the RGU data set containing *MEQ*, *BMDT*, *MSU* and module results. There is evidence that mathematics support has helped students perform better (Patel and Little 2006). However, we do not have enough information from this piece of analysis on the individual student's approaches to studying and mathematical ability and on which mathematics support method works best for individual students.

The analysis is based on data summaries for module results for engineering and computing students at RGU over the years 1999 - 2004. Mathematics modules results are used rather than overall student results to allow for a finer analysis of performance on mathematical skills. The modules included in this study for levels 1 and 2 are given in appendix 14; level 1 modules were taken at year one and level 2 at year two (the first number in the module code representing the level).

3.6.3 Analysis stage 2 – Mathematics support and approaches to studying

At Stage 2 of the analysis more consideration is given to the individual's preference for mathematics support because of *Attitudes* and *AtS.* First year engineering students' *MEQs*, *BMDT* results, *AtS* scores before and after mathematics support intervention and mathematics related module results make up part of the dataset.

The reason for including the *AtS* of second and third year students is to see if earlier learning of mathematics does require the gathering of skills often learnt by memorising and practising, normally considered a surface approach (Au and Entwistle 1999) and not so desired. However, Marton *et al.* (1996) highlighted the paradox of Chinese learners who were nurtured to memorise facts and still progressed to become high academic performers. The assumption the author is making is that initially students will prefer a more surface approach but once skills have been mastered they can be combined to solve applied mathematical problems and be used to develop new solutions hence reflecting the deeper approach.

3.6.4 Analysis stage 3 – Proposed model for improving mathematics support

Using the factors identified in the two stages above, a mathematical model will be produced by using influences on mathematical learning and changes to *AtS*. The model is defined within the context of the mis-matched mathematical proficiency in engineering undergraduates leading to poor performance in main programme of study. Mathematics support was provided to help reduce the mis-match but the students' individual characteristics affect engagement with mathematics support and motivation for learning, thus students' *AtS* and *Attitudes* are considered as are some of the other influencing factors.

4 Data collection

The set of data used in this study has been obtained from various sources described in this section and summarised in Table 8, the subjects in the datasets being from RGU and UoS from faculties of engineering. The data collection sources were the university records systems for mathematics entry qualifications (*MEQ*), mathematics support usage (*MSU*) figures, student feedback records, basic mathematics diagnostic test (*BMDT*) results, approaches to studying (*AtS*) questionnaire responses and module results. The overall dataset comprises of 1028 (33.5%) and 2040 (66.5%) students from RGU and UoS respectively of which 117 (11.4%) and 212 (10.4%) were mathematics support users respectively.

	RGU			UoS			Grand
	Non-MSU	MSU	Total	Non-MSU	MSU	Total	Total
BMDT	466 (83.5%)	92 (16.5%)	**558**	388 (85.7%)	65 (14.3%)	**453**	**1011**
MEQ	911 (88.6%)	117 (11.4%)	**1028**	1828 (89.6%)	212 (10.4%)	**2040**	**3068**
Attitudes	517 (85.0%)	91 (15.0%)	**608**	21 (56.8%)	16 (43.2%)	**37**	**645**
AtS				86 (70.5%)	36 (29.5%)	**122**	**122**
Module Results	534 (82.8%)	111 (17.2%)	**645**	1545 (88.5%)	200 (11.4%)	**1745**	**2390**
TOTAL	**911 (88.6%)**	**117 (11.4%)**	**1028**	**1828 (89.3%)**	**212 (10.4%)**	**2040**	**3068**

Table 8 – Summary of overall datasets for RGU and UoS

4.1 Universities' students records

Records systems were accessed at both Universities to gather data on engineering and computing students' profiles including their mathematics entry qualification(s), programme of study and module results.

4.2 Mathematics support usage and feedback records

Mathematics support usage data recorded at both universities was collected and set out to present usage in a longitudinal manner: in brief, mathematics support usage in first and second years of study, separated with the intention of comparing usage within relevant year of module performance.

The different types of support on offer can also be broken down into '*modes of delivery*': drop-in support offers 'here and now' support with a tutor whereas the booking of support appointments allows for a planned and organised meeting. Web-based and resource-based support can be more individually driven, even allowing for private study at home. The *timing* of accessing support within students' academic courses can also be divided according to modes of delivery; some students will use the support early in their studies to keep up with understanding the main programme of studies. Other students will seek out support as they need it during their programmes whilst others will attend at the end of their course to revise for up-coming exams. In this research there has been no opportunity to collect finer details of mathematics support methods i.e. time/type of usage, therefore have all been put under one mathematics support category.

4.3 Basic mathematics diagnostic test results

In this study the author has used the analysis of the *BMDT* results from the two institutions (RGU and UoS) to identify mathematical skills level and assess entry level skills that are relatively less well developed in engineering students.

At RGU the *BMDT* was administered to the engineering and computing students at the start of their degree in the first few weeks, and has resulted in the accumulation of data comprising of 558 records over 8 years from 1998 to 2006 (excluding 2002 when the tests were not delivered due to technical problems). At UoS the *BMDT* results were only available for year 2009 when the diagnostic test was first introduced by the mathematics help centre to all of the Faculty of Engineering's first year students; the results available in this sample number 453.

The tests for the two universities were different and within each Institute the students were tested on different questions depending on course. Hence at RGU there are three different *BMDT's* and the "pass" mark was 50% or more, whilst at UoS there are two different *BMDT's* but here the pass mark for students was 75% or more. The reason for this difference between the institutes' *BMDT* pass mark was the level the questions were set at for the two Institutes. The questions at UoS were fewer and tested for more basic skills than the ones set at RGU (see appendices 2 and 4).

4.4 Approaches to studying questionnaire responses

Of the 453 students asked to complete the ASSIST+ questionnaire, 115 (18.7%) questionnaire responses (from first year entrants) were obtained but only 105 were usable as 10 were incomplete or had missing user IDs which were needed initially to link to student details prior to response data being anonymised for the analysis.

The same first year students (105) who had fully completed the ASSIST+ questionnaire at the start of the semester were asked to complete a shorter version of the questionnaire at the end of the first semester to identify changes in their *AtS* scores over the period. 25 of these 105 completed the second shorter version at the end of the semester.

Additionally, 358 engineering students in their second or above year-of-study who had made use of mathematics support were asked to complete the same ASSIST+ questionnaire via e-mails with additional questions on *Attitudes* (same three questions used at RGU). 137 (38.3%) of the emails were returned because of deregistered status and of the remaining 221 (61.7%) only 17 (7.7%) completed the questionnaires. The high numbers of returned emails was not unexpected as the mathematics support at UoS has been running since 2007 and most students who made use of mathematics support at the beginning of their courses are presumed to have completed by 2009.

4.5 Attitudes to mathematics

Students' attitudes to mathematics were captured over a number of years for RGU and one year for UoS. Thus included in the dataset are 969 and 37 cases with information on *Attitudes* for RGU and UoS respectively, percentages of these having made use of mathematics support being 15.7% and 43.2%.

The *Attitudes* questions were part of the *BMDT* at RGU; for UoS they were part of the Shorter ASSIST+ questionnaire presented to first year students who had completed the questionnaire at the beginning of the session and then after the first semester, 21 were completed and the remaining 16 (not including the 5 that did not complete the *Attitudes* part of the questionnaire) by students in their second and third year of studies who made use of mathematics support. The Shorter ASSIST+ questionnaire had a reduced number of questions based on the shorter version of ASSIST (ETL 2005) detailed in section 3.4.1.

4.6 Mathematics module results

Mathematics module results were collected through the Universities' record systems for levels 1 and 2 (first year students did level 1 modules and second year students did level 2). Overall there were 2390 cases with module results: 645 from RGU and 1745 from UoS; of these 111 and 200 respectively were *MSU* students (in percentages these are 17.2% and 11.5%). The details of the modules are provided in appendix 14. For the RGU dataset it is the module grades that are used in the analysis rather than module marks as for the UoS dataset. The reason for this is that in 2002 RGU decided to use grades for their assessment results instead of marks (Laing and Hornby 2003). As a result we have a more complete set of results for grades than for marks. However, grades do not lend themselves to parametric testing thus non-parametric tests were used for the RGU module results analysis and parametric tests are used for the UoS data since parametric tests provide greater discriminatory power. A more detailed breakdown of the datasets against mathematics support usage is provided in Table 9 and Table 10 for RGU and UoS respectively.

	Module Results			
	MSU Categories	**No Results Available**	**Results Available**	**Total**
No BMDT Results Available	0 Visits	286 (64.3 %)	159 (35.7%)	445
	1 Visit	1 (25.0%)	3 (75.0%)	4
	2-5 Visits	0 (0.0%)	11 (100.0%)	110
	6 or more Visits	0 (0.0%)	10 (100.0%)	1
	Total	**287 (61.1%)**	**183 (38.9%)**	**470**
BMDT Results Available	0 Visits	91 (19.5%)	375 (80.5%)	466
	1 Visit	2 (10.5%)	17 (89.5%)	19
	2-5 Visits	2 (6.1%)	31 (93.9%)	33
	6 or more Visits	1 (2.5%)	39 (97.5%)	40
	Total	**96 (17.2%)**	**462 (82.8%)**	**558**
	GRAND TOTAL	**383 (37.3%)**	**645 (62.7%)**	**1028**

Table 9 – Summary of dataset – RGU undergraduate engineering and computing students (1996- 2005)

	Module Results			
	MSU Categories	**No Results Available**	**Results Available**	**Total**
No BMDT Results Available	0 Visits	436 (30.3 %)	1004 (69.7%)	1440
	1 Visit	5 (13.5%)	32 (86.5%)	37
	2-5 Visits	7 (12.1%)	51 (87.9%)	58
	6 or more Visits	19 (36.5%)	33 (63.5%)	52
	Total	**467 (29.4%)**	**1120 (70.6%)**	**1587**
BMDT Results Available	0 Visits	8 (2.1%)	380 (97.9%)	388
	1 Visit	1 (5.0%)	19 (95.0%)	20
	2-5 Visits	1 (4.5%)	21 (95.5%)	22
	6 or more Visits	1 (4.3%)	22 (95.7%)	23
	Total	**11 (2.4%)**	**442 (97.6%)**	**453**
	GRAND TOTAL	**478 (23.4%)**	**1562 (76.6%)**	**2040**

Table 10 – Summary of dataset – UoS undergraduate engineering and computing students (2005 – 2009)

5 Data analysis

This chapter addresses the first two stages of the analysis described in chapter 3; those of measuring the effectiveness of mathematics support and mathematics support students' preferences for approaches to studying. The analysis begins with the use of the RGU dataset to measure the effectiveness of mathematics support with the use of the basic mathematics diagnostic test results. The analysis of the UoS dataset is a continuation of measuring effectiveness of mathematics support in terms of student progression but goes into further detail by considering students' approaches to studying (*AtS*). The *AtS* factor will be used to remove the bias of the data sample which was not randomly collected. Additionally how the students' *AtS* scores affect progression and influence mathematics support usage is considered. The analysis of mathematics support here was based on work at the mathematics support centres at RGU and UoS over the years 1996-2005 and 2007-2009 respectively. Both support centres provided and to date continue to provide additional help in mathematics and statistics.

The correlations between the independent, dependent and intervention variables examined are provided here with Figure 9 summarising the schema of the variables and tables 63 and 64 in appendix 2 provides details of the variable data type and characteristics. The independent variables were Mathematics Entry Qualifications (*MEQ*), Basic Mathematics Diagnostic Test (*BMDT)* scores, *Attitude-1* (Confidence in mathematics), *Attitude-2* (Liking for mathematics), *Attitude-3* (Past experience of mathematics learning) and Approaches to Studying *(AtS)* or AtS_{Pre} (*AtS* Pre-intervention) scores, dependent variables being AtS_{Post} (*AtS* Post-intervention) scores and module results with the intervention Mathematics Support Usage (*MSU*). Note the *AtS* scores were only available for the UoS dataset.

To summarise, the independent variables were all the pre-mathematics support intervention variables i.e. *BMDT*, *MEQ*, *Attitudes-(1-3)* and AtS_{Pre}, with module results and AtS_{Post} at the end of the year being dependent variables post-mathematics support intervention.

The analysis reviewed students' mathematical skills base through the use of mathematics entry qualifications and the results of *BMDT*. Students *Attitudes-(1-3)* towards mathematics and *AtS* were used for student profiling. The performance by the students was measured using the results of mathematics modules, namely the differences in performance for non-mathematics support usage students (*Non-MSU*) and mathematics support usage students (*MSU*). The performance by *Non-MSU* and *MSU* students is cross tabulated against initial mathematical skills base to measure the value added by mathematics support.

5.1 Characteristics of mathematics support users

For simplicity, the *MEQ's* have been categorised as *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* (including Access courses) and age-groups have been categorised as *17-21* and *22 or over*. The categories for the *MEQ's* have been selected to differentiate between students with traditional and non-traditional entry qualifications for HE and the age-groups categories to identify School leavers and Returners to HE.

The *MSU* groups have been set at; *0 Visits* for *Non-MSU*, *1 Visit* only, *2-5 Visits* and *6 or more Visits*. These categories were selected because from a previous study (Patel 2004) 1-4 visits was the most common usage group but it was considered important to separate the single visits which do not indicate full engagement with mathematics support. High usage of mathematics support was not assumed to be preferred as this could mean dependency thus the *"2-5 visits"* group was selected as there was a tendency for students to use the support in the first half of the semester after which they are happier working through mathematics via regular means and the "6 or more" category is intended to capture the rest of the students.

5.1.1 Characteristics - Age groups

Table 11 gives a summary of student numbers and percentages categorised by age group and *MSU* categories for the whole dataset for RGU. Chi-square test of differences for each of the age groups are 1.335 and 1.931 with a df=3. However the results for the differences between the age groups and their entry qualifications for RGU are not statistically significant but are significant for UoS with Chi-squares of 175.015 and 13.389. This again highlights the limitations of the RGU dataset noted in chapter 3.

Age at Entry	**MEQ Type**	**O/E**[4]	**0 Visits**	**1 Visit**	**2-5 Visits**	**6 or more Visits**	**Total**
17-21	A-Level, Highers or Sixth Year Studies	O	328 (85.0%)	12 (85.7%)	20 (76.9%)	32 (86.5%)	392
		E	326.8	11.9	22.0	31.3	
	Vocational or Foundation	O	58 (15.0%)	2 (14.3%)	6 (23.1%)	5 (13.5%)	71
		E	59.2	2.1	4.0	5.7	
22 and Over	A-Level, Highers or Sixth Year Studies	O	8 (44.4%)	1 (50.0%)	0 (0.0%)	2 (28.6%)	11
		E	6.8	0.8	0.8	2.7	
	Vocational or Foundation	O	10 (55.6%)	1 (50.0%)	2 (100%)	5 (71.4%)	18
		E	11.2	1.2	1.2	4.3	
	TOTAL		**404 (82.1%)**	**16 (3.3%)**	**28 (5.7%)**	**44 (8.9%)**	**492**

Table 11 – MEQ Types for MSU groups by Age groups for RGU

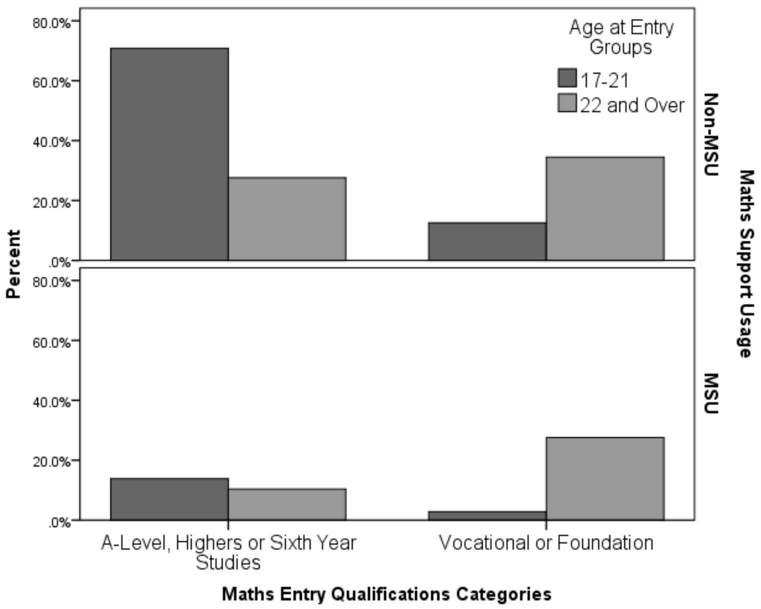


Chart 3 – MEQ types by age groups and Non-MSU/MSU for RGU

[4] O=Observed, E=Expected

The majority of students at RGU had Scottish Higher qualifications and the highest level users of mathematics support were the non-traditional entry students i.e. *Vocational or Foundation*.

There were proportionally more *Vocational or Foundations* students in the *22 and Over* age group category (see Chart 3 and Chart 4) making use of mathematics support.

Age at Entry	MEQ Type	O/E[5]	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
17-21	A-Level, Highers or Sixth Year Studies	O	1 743 (98.6%)	46 (90.2%)	62 (84.9%)	48 (75.0%)	1899
		E	1716.4	49.5	70.9	62.2	
	Vocational or Foundation	O	24 (1.4%)	5 (9.8%)	11 (15.1%)	16 (25.0%)	56
		E	50.6	1.5	2.1	1.8	
22 and Over	A-Level, Highers or Sixth Year Studies	O	34 (91.9%)	3 (60.0%)	2 (33.3%)	7 (63.6%)	46
		E	28.8	3.9	4.7	8.6	
	Vocational or Foundation	O	3 (8.1%)	2 (40.0%)	4 (66.7%)	4 (36.4%)	13
		E	8.2	1.1	1.3	2.4	
	TOTAL		**1804 (89.6%)**	**56 (2.8%)**	**79 (3.9%)**	**75 (3.7%)**	**2014**

Table 12 – MEQ Types for MSU groups by Age groups for UoS

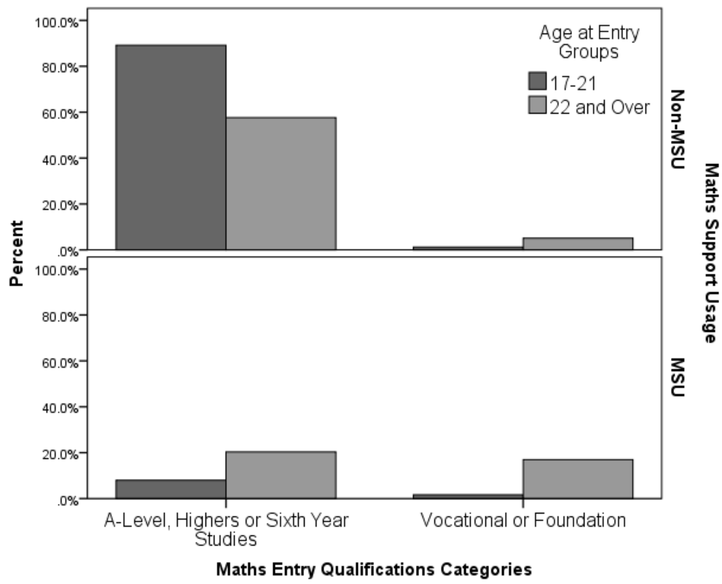


Chart 4 – MEQ types by age groups and Non-MSU/MSU for UoS

[5] O=Observed, E=Expected

The largest age group relatively in both institutes was the *17-21 years* group making use of *MSU* within the *A-Level, Highers or Sixth Year Studies*. The largest group in the *Vocational or Foundation* entry qualifications was the *22 and over* age group though the actual numbers are very low (Table 11 and Table 12).

5.1.2 Characteristics – Mathematics entry qualifications

The analysis on the *MEQ's* by mathematics support gave chi-squares of 23.123 and 216.4 for RGU and UoS (Table 13 and Table 14) respectively with significance to $p<0.05$ and degrees of freedom at 3. The chi-square distribution table in appendix 15 shows that the computed chi-squares lie beyond the 0.001 significance ($p<0.001$) and as the chi-square statistic exceeds the critical value in the table for 0.05 probability level, the null hypothesis of equal distributions is rejected. Hence the differences in the observed values at both institutes are significant bearing in mind the limitations of the RGU dataset.

	MEQ Types	O/E	Non-MSU	1 Visit	2-5 Visits	6 or more Visits	Total
$\chi^2=23.123$ df=3 $p<0.001$	A-Level, Highers or Sixth Year Studies	O	767 (84.2%)	16 (69.6%)	27 (61.4%)	35 (70.0%)	**845**
		E	748.8	18.9	36.2	41.1	**(82.2%)**
	Vocational or Foundation	O	144 (15.8%)	7 (30.4%)	17 (38.6%)	15 (30.0%)	**183**
		E	162.2	4.1	7.8	8.9	**(17.8%)**
	Total		**911 (88.6%)**	**23 (2.2%)**	**44 (4.3%)**	**50 (4.9%)**	**1028**

Table 13 - Types of MEQ's in sample for RGU for MSU categories

For RGU the largest numbers for the *A-Level, Highers or Sixth Year Studies* group was within the *Non-MSU* category (84.2%) and the smallest was the *2-5 visits* category (61.4%). In the *Vocational or Foundations* group the largest and smallest proportions were for *2-5 visits* and *Non-MSU* categories respectively.

	MEQ Types	O/E	Non-MSU	1 Visit	2-5 Visits	6 or more Visits	Total
χ^2=216.4 df=3 p<0.001	A-Level, Highers or Sixth Year Studies	O	1801 (98.5%)	50 (87.7%)	65 (81.2%)	55 (73.3%)	**1971**
		E	1766.2	55.1	77.3	72.5	**(96.6%)**
	Vocational or Foundation	O	27 (1.5%)	7 (12.3%)	15 (18.8%)	20 (26.7%)	**69**
		E	61.8	1.9	2.7	2.5	**(3.4%)**
	Total		**1828 (89.6%)**	**57 (2.8%)**	**80 (3.9%)**	**75 (3.7%)**	**2040**

Table 14 - Types of MEQ's in sample for UoS for MSU categories

For UoS the largest proportions for the *A-Level, Highers or Sixth Year Studies MEQ* groups is within the *Non-MSU* category (98.5%) and the smallest is the *6 or more visits* category (73.3%). In the *Vocational or Foundations* group the largest and smallest are *6 or more visits* and *Non-MSU* categories respectively. Thus attendance by *MEQ* groups was similar at both Institutes in that the *Vocational or Foundations* group made more use of mathematics support.

Overall in terms of actual percentages RGU had a higher number of vocational entrants (17.8%) than UoS (3.4%) (Tables 13 and 14). This is not unexpected for Post-92 and Russell Group Universities but it is interesting that *Vocational or Foundation* students continued to increase engagement with mathematics support beyond 5 visits at UoS.

Of the 117 *MSU* students in the RGU dataset one third were from the *Vocational and Foundation* students and of the 212 *MSU* students at UoS one fifth were from the *Vocational and Foundation* background. Considering the total intake ratio of 1 to 10 of *MSU* to *Non-MSU* the numbers of *Vocational and Foundation* students attending for support were proportionately higher at both institutes. The implications of this are that for this group of mathematics support students entry qualifications are not well matched to the majority of course material; as these tend to be written for students with traditional entry qualifications (*A-levels, Highers or Sixth Year Studies*). Therefore in these cases mathematics support becomes a vital 'filling in the gaps' service due to the difference between mathematics skills expected on entry and those actually present (Parsons 2005; Hobson and Rossiter 2010).

A similar breakdown of the *MEQ* types by *MSU* categories was carried out by grouping the points and grades into grade groups of *Well Prepared* and *Less Well Prepared* as categorised in a study by Symonds, Lawson *et al*. (2010) for A-Level grades A-C for *Well Prepared* and the rest including vocational and foundation qualifications deemed as *Less Well Prepared*. For the non-A-level and non-Highers results the qualification points were converted into grades before assigning them to the grade categories deemed acceptable as the entry qualification points are comparable UCAS Tariff points.

	MEQ Level	O/ E	Non-MSU	1 Visit	2-5 Visits	6 or more Visits	Total
$\chi^2=12.406$ df=3 $p<0.005$	Well prepared	O	675 (90.6%)	12 (1.6%)	25 (3.4%)	33 (4.4%)	**745 (72.5%)**
		E	660.2	16.7	31.9	36.2	
	Less well prepared	O	236 (83.4%)	11 (3.9%)	19 (6.7%)	17 (6.0%)	**283 (27.5%)**
		E	250.8	6.3	12.1	13.8	
	TOTAL		**911 (88.6%)**	**23 (2.2%)**	**44 (4.3%)**	**50 (4.9%)**	**1028**

Table 15 – Mathematical preparedness level's for RGU for MSU groups

	MEQ Level	O/E	Non-MSU	1 Visit	2-5 Visits	6 or more Visits	Total
$\chi^2=115.9$ df=3 $p<0.001$	Well prepared	O	1712 (91.5%)	48 (2.6%)	65 (3.5%)	4 (2.5%)	**1871 (91.7%)**
		E	1676.6	52.3	73.4	68.8	
	Less well prepared	O	116 (68.6%)	9 (5.3%)	15 (8.9%)	29 (17.2%)	**169 (8.3%)**
		E	151.4	4.7	6.6	6.2	
	TOTAL		**1828 (89.6%)**	**57 (2.8%)**	**80 (3.9%)**	**75 (3.7%)**	**2040**

Table 16 – Mathematical preparedness level's for UoS for MSU groups

With *this* breakdown in terms of mathematical *Preparedness* more than a 100 *Non-MSU* students in each Institute from the *A-Level, Highers or Sixth Year Studies* category were moved to the *Less Well Prepared* (with all the *Vocational or Foundations* students). The change is substantial under this categorisation when considering the institutes separately; at RGU there was an increase (of the better qualified/prepared) of 6.4% (90.6%-84.6%) and a decrease of 7% at UoS in the *Non-*

MSU. One of the differences between the two institutes is their entry qualifications requirements at RGU being lower than at UoS. Therefore, this increase in the *Non-MSU* for the better qualified/prepared students at RGU is not completely unexpected as they are less likely to need additional mathematics support (and vice versa for UoS). The difference may also be due the incomplete data for the RGU dataset which was collected in 2006 with no option to return to gather potentially missing data.

An additional review (see appendix 16) by preparedness was carried out to examine best grouping of *MEQ* types. However, due to the differences on the curriculum for traditional and non-traditional mathematics entry qualifications the conversion of UCAS Tariff points into grades is at least poor if not flawed. Hence it is the *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* breakdown that is deemed more appropriate for this study as it is considering students' mathematical skills.

There was also a significant difference in the age at entry means for these two groups, with a mean age of 18.46 and 20.42 for *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* entrants respectively. The more sustained mathematics usage category is significantly correlated to age for *Vocational or Foundations* entrants as can be seen in Chart 5.

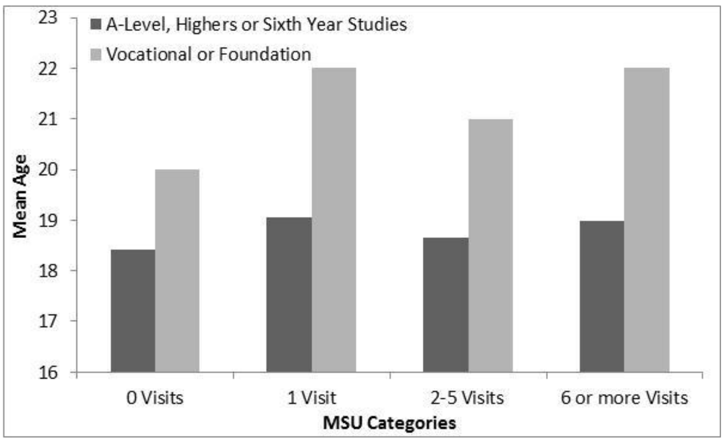


Chart 5 – Age means for MEQ by MSU categories

Finally, Chart 6 and Chart 7 show the *MSU* visits by *MEQ* types for RGU and UoS respectively and show that the institutes have differing mathematics support usage behaviours. RGU had sustained engagement with mathematics support by students who were *A-Level, Highers or Sixth Year Studies* whereas at UoS their engagement seems to drop after the 2-5 visits category. For the *Vocational or Foundations* at UoS all the *MSU* categories attract similar usage but at RGU there was less sustained usage of support.

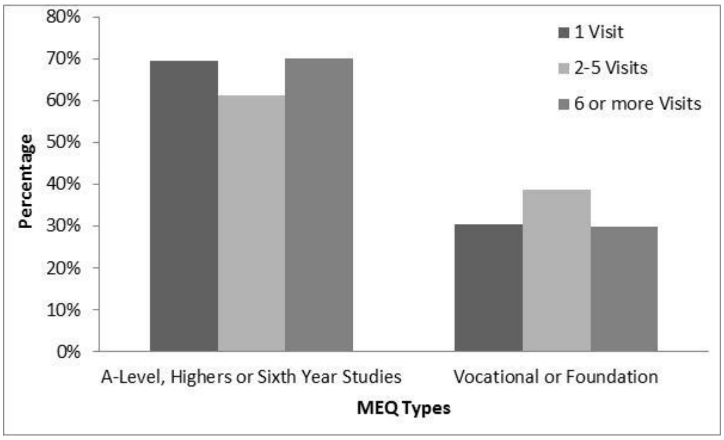


Chart 6 – RGU: MSU categories by MEQ types

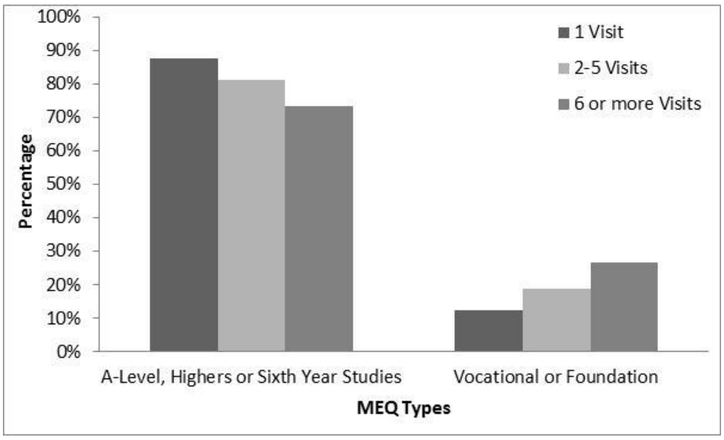


Chart 7 – UoS: MSU categories by MEQ types

Overall the results suggest mathematics support was attracting students with good mathematical skills possibly wanting to further improve their scores as seen in the study by Pell and Croft (2008) and evidenced here in this research. The usage pattern of the *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* students was different at the two institutes. Possible reasons apart from actual qualifications could be motivation, attitudes, confidence and approaches to studying, the latter being explored further in this research.

The *MEQ* scores represent the highest UCAS tariff points for the *MEQ* obtained before enrolment but do not indicate when these points were gained and because the tariff points are not continuous they will be analysed using non-parametric tests. The *BMDT* percentages give a better indication of students' actual mathematical knowledge at the start of the programme of studies whereas the *MEQ* points show the highest level of mathematics studied and do not take into account any weakening effect due to forgetting and/or lack of practice and use of mathematics. Although *MEQ* and *BMDT* results do not give us the students' mathematical ability they do give us comparable measures of knowledge and are therefore deemed useful.

Independent samples t-tests have been used for the analysis as they allow for an alternative set of statistics for results where variance in the groups cannot be assumed. This was also preferable because *MEQ* and Module grades, after conversion from *MEQ* points and Module marks (because of the grades bands Table 17) were not normally distributed. However, the sample sizes are large enough (greater than 100) to enable valid independent samples t-tests.

Percentage Mark	Grade	Result
69.50 – 100	6	Pass
59.50 – 69.49	5	Pass
49.50 – 59.49	4	Pass
39.50 – 49.49	3	Pass
34.50 – 39.49	2	Borderline
00.00 – 34.49	1	Fail

Table 17 – Conversion table for marks to grades

The means of *MEQ* grades for RGU and UoS students studying specified mathematics modules are provided in Table 18 and Table 19. The *MEQ* means for the *MSU* students are lower than the *Non-MSU* students, however only 4 of the independent samples t-tests are statistically significant. The magnitude of the differences measured using Cohen's d effect size (Equation 1) ranging from *small* to *large,* of the significant 3 were *medium* and 1 *large.*

Level 1 Modules	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	df	sig (2-tailed)	Mean Difference	Std. Error Difference	
CM1003	242	3.71	1.311	23	3.09	0.596	N	4.125	263	0.000	0.620	0.150	0.5
CM1900	105	3.66	0.897	20	3.50	1.100	Y	0.692	123	0.490	0.157	0.227	0.2
CM1901_2	43	4.47	0.882	19	4.42	0.838	Y	0.184	60	0.855	0.044	0.239	0.1

Table 18 - RGU MEQ grades summaries for the Independent-samples t-test for Non-MSU and MSU

Level 1 Modules	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	df	sig (2-tailed)	Mean Difference	Std. Error Difference	
ACS123	118	4.72	1.190	14	4.57	1.016	Y	0.449	130	0.654	0.149	0.332	0.1
COM1002	75	5.09	1.080	2	4.50	0.707	Y	0.770	75	0.444	0.593	0.771	0.6
MAS001_2	19	3.42	1.427	6	3.00	1.265	Y	0.645	23	0.525	0.421	0.652	0.3
MAS140	90	5.31	0.882	11	4.91	0.944	Y	1.416	99	0.160	0.402	0.284	0.5
MAS143_4	346	5.60	0.717	43	5.00	1.069	N	2.571	46.804	0.001	0.598	0.168	0.8
MAS145_6	119	4.66	1.076	34	4.09	1.164	Y	2.702	151	0.008	0.576	0.213	0.5
MAS147_8	252	5.61	0.668	40	5.15	1.075	Y	3.682	290	0.001	0.461	0.125	0.6
MAS149_50	445	5.43	0.809	35	5.20	1.106	N	1.189	36.919	0.242	0.227	0.191	0.3

Table 19 - UoS MEQ grades summaries for the Independent-samples t-test for Non-MSU and MSU

Cohen's $d_{eqv} = \dfrac{(\bar{x}_1 - \bar{x}_2)}{\sigma}$

0.2 = Small effect size

0.5 = Medium effect size

0.8 = Large effect size

Equation 1 – Cohen's d for equal variance or one sample t-tests

Cohen's $d_{uneqv} = \dfrac{(\bar{x}_1 - \bar{x}_2)}{\sigma_{pooled}}$

$$\sigma_{pooled} = \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2}}$$

Equation 2 – Cohen's d for unequal variance or independent samples t-tests with pooled sample standard deviation

$$R^2 = \left(\frac{d}{\sqrt{d^2 + {}^1/_{pq}}}\right)^2$$

Where d is the Cohen's d with p being the proportion of one group in the combined two groups population and q the 1-p (i.e. proportion of the other group) (Cohen 1988).

<u>**Alternatively**</u>

$$R^2 = \frac{SS_{reg}}{SS_{tot}}$$

Where SS_{reg} is the regression sum of squares and SS_{tot} the total sum of squares

R^2 = 0.01 – 0.08	Small effect size
R^2 = 0.09 – 0.24	Medium effect size
R^2 = 0.25 and above	Large effect size

Equation 3 – R^2: Influence of variable

5.1.3 Characteristics – Basic mathematics diagnostic test results

Another measure of mathematical skills is the Basic Mathematics Diagnostic test (*BMDT*). At RGU most of the first year students on engineering and computing (at time of data collection in 2006) courses were diagnosed for their mathematical skills at the start of their studies. Only students whose mathematics entry qualifications were known were included in the analysis. At UoS a diagnostic test was rolled out to the whole Faculty of Engineering for the first time in 2009 the results of which form part of this analysis.

For both Institutes, after student completion of diagnostic tests, staff were provided with a summary of the results to use for streaming students (if appropriate to the department) but more importantly to help perform pastoral duties. Based on the diagnostic results the students were provided with learning programmes (see samples in appendices 5 and 6) to help them revise the areas that were highlighted as needing strengthening. There were some students[6] who registered late and were not exposed to the *BMDT* and as such had become part of the control group for *BMDT*. This had the potential of introducing a bias in the control group in that these students may not be coming in from the traditional school-leaver background or that their the chosen programme of study may not have been their first choice (coming late through clearing), causing a motivation issue, but because of the small numbers of these students (less than 1%) this phenomenon is not expected to undermine the analysis. It should be stated that the mathematics diagnostic tests only evaluated prior knowledge and did not identify the *potential* for mathematical learning, the analysis of students' approaches to studying in section 5.3 will look into the latter in more detail.

This principle of early diagnosis can and has been part of mathematics support mechanism for many years now (Lawson, Halpin *et al.* 2001; Pell and Croft 2008)

[6] The numbering less than 1% of the cohort

and has also been applied in other subjects; for example, Entwistle (2003) used a diagnostic test for the identification of the needs of study skills; this had a wider application due to its usefulness in all disciplines. Apart from the provision of remediation and induction Entwistle (2003) goes further and suggests curricular design and teaching methods to help improve performance. The latter consideration was beyond the scope of this research which is restricted to the provision of mathematics support as a means of addressing identified gaps in mathematical ability.

There were three different RGU diagnostic tests and two UoS diagnostic tests and the questions for all were a subset of the full test shown in appendix 2 with the questions for each test detailed in appendix 7.

The independent-samples t-test conducted to compare *BMDT* percentages for *Non-MSU* and *MSU* (Table 20 and Table 21) showed significant ($p<0.05$) differences for 5 out of the 11 cohorts (highlighted in grey). The means for *MSU* students were smaller for all except 2 (COM1002 and MAS001_2).

The magnitude for the differences between the mean percentages is measured using Cohen's (1988 p40) d_{eqv} and using pooled standard deviation (σ_{pooled}) to take account of unequal variances. The magnitudes (effect size) of the difference of the significant results for *BMDT* were between 0.5 and 0.8 which according to Cohen's (1988) guidelines are *medium* to *large*.

Module groups	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	df	sig (2-tailed)	Mean Difference	Std. Error Difference	
CM1003	138	58.78	14.031	11	38.09	18.950	Y	4.581	147	0.000	20.692	4.517	1.4
CM1900	91	50.98	15.655	18	40.06	17.227	Y	2.660	107	0.009	10.922	4.106	0.7
CM1901_2	36	61.08	12.573	18	58.89	12.266	Y	0.609	52	0.545	2.194	3.601	0.2

Table 20 - RGU BMDT percentages summaries for the Independent-samples t-test for Non-MSU and MSU

BMDT Percentage by Modules	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	df	sig (2-tailed)	Mean Difference	Std. Error Difference	
ACS123	28	78.32	8.641	6	70.17	11.669	Y	1.975	32	0.057	8.155	4.130	0.9
COM1002	62	81.95	12.047	1	87.00			-.0416	61	0.679	-5.048	12.144	-0.4
MAS001_2	5	75.40	13.903	2	81.50	14.849	Y	-.517	5	0.627	-6.100	11.795	-0.5
MAS140	56	86.14	7.960	2	81.50	10.607	Y	0.805	56	0.424	4.643	5.768	0.6
MAS143_4	71	86.82	7.730	19	65.42	21.788	N	4.210	19.227	0.000	21.396	5.082	1.8
MAS145_6	12	69.58	17.661	13	49.46	21.643	Y	2.534	23	0.019	20.122	7.942	1.1
MAS147_8	44	88.20	6.705	9	85.89	8.238	Y	0.908	51	0.368	2.316	2.549	0.3
MAS149_50	100	84.55	13.948	11	60.09	28.539	N	2.806	10.532	0.018	24.459	8.717	1.6

Table 21 - UoS BMDT percentages summaries for the Independent-samples t-test for Non-MSU and MSU

Except for two UoS Modules (COM1002 and MAS001_2) the *BMDT* percentage means of the *Non-MSU* students were higher than for *MSU* students at both Institutes indicating similar results for mathematical skills as with the *MEQ* results where the *Non-MSU* students had higher mathematical skills scores than the *MSU* students at the beginning of the course.

Although the mean *BMDT* percentages for modules COM1002 and MAS001_2 were larger than *MSU,* COM1002 only had one case in *MSU* and only two cases in MAS001_2. The low numbers make these two and MAS140 results too weak for consideration and these have therefore not been included in the rest of the analysis. The ACS123 mathematics module is also not included any further as it uses a different approach to teaching and was analysed separately for another publication looking at the effect of the different approach (Patel and Rossiter 2011). The magnitudes of the difference for *BMDT* are overall *large* and only one difference is *small* (not considering the four modules that were removed).

		MEQ		BMDT	
Institute	**Module groups**	**Differences in grades means**	**Cohen's d**	**Differences in percentages means**	**Cohen's d**
RGU	CM1003	0.620	0.5	20.692	1.4
RGU	CM1900	0.157	0.2	10.922	0.7
RGU	CM1901_2	0.044	0.1	2.194	0.2
UoS	MAS143_4	0.598	0.8	21.396	1.8
UoS	MAS145_6	0.576	0.5	20.122	1.1
UoS	MAS147_8	0.461	0.6	2.316	0.3
UoS	MAS149_50	0.227	0.3	24.459	1.6

Table 22 – Mean differences for Non-MSU and MSU for MEQ and BMDT results

The mathematical skills of the mathematics support students were lower than the non-mathematics support students at the beginning of the course. This was also the case for studies by Croft and Grove (2006), Patel and Little (2006) and Mac an Bhaird, Morgan *et al,* (2009) which showed that most *MSU* students were weaker.

Another finding in these studies was that mathematics support also attracted the more able students (Croft and Grove 2006). The analysis establishes that the *MSU* students in this dataset (Table 22) have considerably lower mathematical skills at the start of their studies. It is not just the students' mathematical skills that affect performance; hence the next section examines the students' attitudes towards mathematics to better profile *MSU* students.

5.1.4 Characteristics – Attitudes towards mathematics

The responses to three questions on attitudes towards mathematics and experiences of mathematics (Section 4.5) were used to examine if students' attitudes had an influence on mathematics support usage and/or performance on mathematics modules.

Summaries are given of the numbers of results available for the students' *Attitude-1* (confidence) in Table 23, *Attitude-2* (liking) in Table 24 and *Attitude-3* (past experience) in Table 25 categorised by *MSU* visits frequency and mathematical skills level. Following on from the mathematical skills levels based on entry qualifications *Attitudes* have been compared: *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* by mathematics support usage groups. 92 students were *Vocational or Foundations* and 553 were *A-Level, Highers or Sixth Year Studies,* 10 and 27 of these were from UoS respectively, the remainder being from RGU.

The outcomes of these results are only provided for information as there was no significance and notable pattern. The groups with the higher observed counts than expected are highlighted in grey.

Vocational and Foundations students made more than expected use of mathematics support regardless of their confidence levels, though the confident student made more sustained use of support (Table 23). There was less engagement with support by *Well Prepared* students with negative confidence and better engagement by the confident and *A-Level, Highers or Sixth Year Studies* students.

	Confidence in maths ability	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
Vocational or Foundation	Poor, Less than adequate or Adequate	51 (69.9%)	4 (5.5%)	10 (13.7%)	8 (11.0%)	**73**
		50.9	4.1	9.8	8.2	
	Exceptional or Good	11 (68.8%)	1 (6.3%)	2 (12.5%)	2 (12.5%)	**16**
		11.1	0.9	2.2	1.8	
	Total	**62 (69.7%)**	**5 (5.6%)**	**12 (13.5%)**	**10 (11.2%)**	**89**
Highers or Sixth Year Studies	Poor, Less than adequate or Adequate	323 (87.3%)	17 (4.6%)	14 (3.8%)	16 (4.3%)	**370**
		316.4	14.7	14.7	24.1	
	Exceptional or Good	149 (81.9%)	5 (2.7%)	8 (4.4%)	20 (11.0%)	**189**
		155.6	7.3	7.3	11.9	
	Total	**472 (85.5%)**	**22 (4.0%)**	**22 (4.0%)**	**36 (6.5%)**	**552**

Table 23 – Attitude 1 Confidence in mathematics ability for MEQ types by MSU groups

For Attitude 2 (*Liking for mathematics*) *A-Level, Highers or Sixth Year Studies* and *Vocational or Foundations* students made sustained use (*6 or more visits*) of support if they liked mathematics.

	Liking for maths	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
Vocational or Foundation	Don't find maths interesting, enjoyable or am indifferent	88 (82.2%)	6 (5.6%)	8 (7.5%)	5 (4.7%)	**49**
		85.4	5.4	7.2	9	
	Find maths interesting or enjoyable	54 (76.1%)	3 (4.2%)	4 (5.6%)	10 (14.1%)	**34**
		56.6	3.6	4.8	6	
	Total	**142 (79.8%)**	**9 (5.1%)**	**12 (6.7%)**	**15 (8.4%)**	**83**
Highers or Sixth Year Studies	Don't find maths interesting, enjoyable or am indifferent	294 (87.0%)	14 (4.1%)	14 (4.1%)	16 (4.7%)	**338**
		288.9	13.5	13.5	22.1	
	Find maths interesting or enjoyable	177 (83.1%)	8 (3.8%)	8 (3.8%)	20 (9.4%)	**213**
		182.1	8.5	8.5	13.9	
	Total	**471 (85.5%)**	**22 (4.0%)**	**22 (4.0%)**	**36 (6.5%)**	**551**

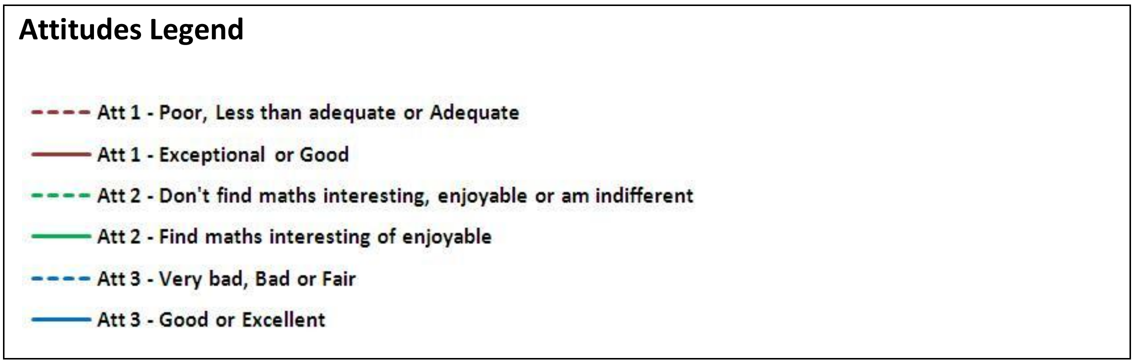
Table 24 – Attitude 2 Liking for mathematics for MEQ types by MSU groups

	Past experience	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
Vocational or Foundation	Very bad, Bad or Fair	38 (70.4%)	3 (5.6%)	5 (9.3%)	8 (14.8%)	**54**
		38.9	2.6	5.9	6.6	
	Good or Excellent	21 (75.0%)	1 (3.6%)	4 (14.3%)	2 (7.1%)	**28**
		20.1	1.4	3.1	3.4	
	Total	**59 (72.0%)**	**4 (4.9%)**	**9 (11.0%)**	**10 (12.2%)**	**82**
Highers or Sixth Year Studies	Very bad, Bad or Fair	187 (82.0%)	11 (4.8%)	12 (5.3%)	18 (7.9%)	**228**
		194.8	9.1	9.1	15.0	
	Good or Excellent	282 (87.9%)	11 (3.4%)	10 (3.1%)	18 (5.6%)	**321**
		274.2	12.9	12.9	21.0	
	Total	**469 (87.9%)**	**22 (4.0%)**	**22 (4.0%)**	**36 (6.6%)**	**549**

Table 25 – Attitude 3 Past experience of learning mathematics for MEQ types by MSU groups

Past Experience gives a different picture to the other 2 *Attitudes.* Here poor past experiences led to better engagement with mathematics support and good experience resulted in less engagement.

Overall, regardless of the mathematical skills levels, students with negative *Attitudes* (dotted lines in Chart 8) had a higher frequency of *MSU* though the *A-Level, Highers or Sixth Year Studies* students used support more consistently (Chart 9 highlighting *6 or more visits*) .



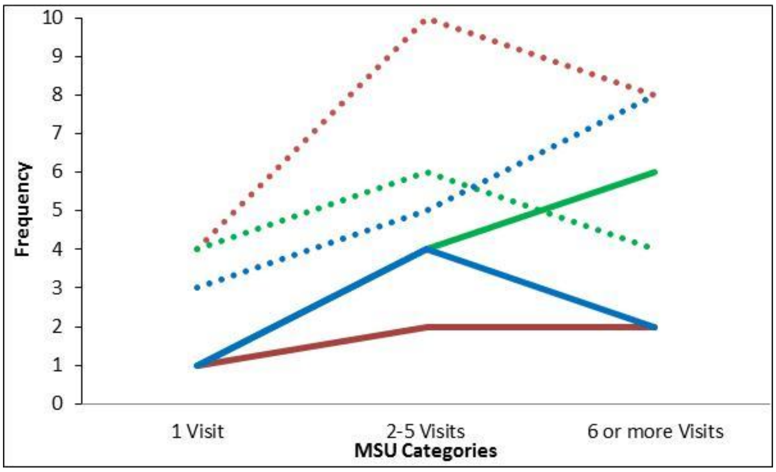


Chart 8 – *Vocational or Foundations* students for Attitudes by MSU categories

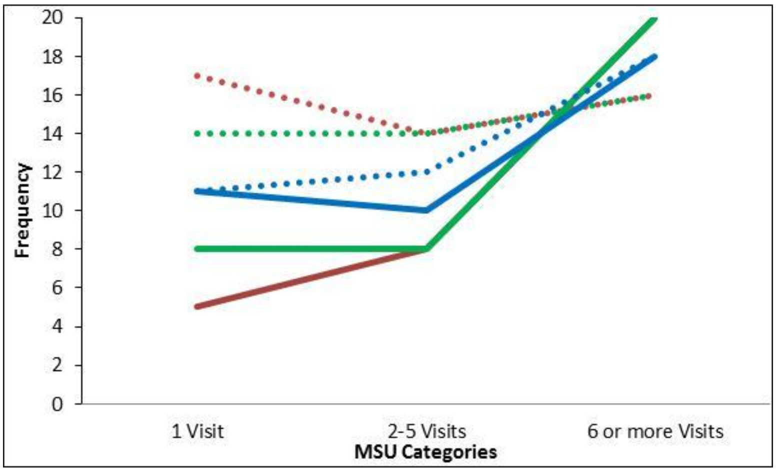


Chart 9 – *A-Level, Highers or Sixth Year Studies* students for Attitudes by MSU categories

5.2 Mathematics performance: value added by mathematics support

The following section identifies the relationship between mathematics support usage and module results at both Institutes. Module passes and fails for the two institutes are summarised in Table 26 and Table 27. At RGU two out of the three level 1 modules' *MSU* students performed better but on CM1003 (computing mathematics) the *Non-MSU* students did better. At level 2, *MSU* did significantly better and the numbers expected in terms of passing, surpassed by 7 compared to 4 in the largest difference in the *Non-MSU* group i.e. CM1003.

RGU Modules		Non-MSU Fail	Non-MSU Pass	Non-MSU Total	MSU Fail	MSU Pass	MSU Total
CM1003 Sig. p<0.05	**O**	16 (6.6%)	227(93.4%)	243	6 (26.1%)	17 (73.9%)	23
	E	20.1	222.9		1.9	21.1	
CM1900 Not Sig.	**O**	19 (18.1%)	86 (81.9%)	105	3 (15.0%)	17 (85.0%)	20
	E	18.5	86.5		3.5	16.5	
CM1901_2 Not Sig.	**O**	7 (17.1%)	34 (82.9%)	41	0 (0.0%)	17 (100%)	17
	E	4.9	36.1		2.1	14.9	
Module Level 2							
CM2900_1 Sig. p<0.05	**O**	33 (13.6%)	210 (86.4%)	243	2 (2.4%)	83 (97.6%)	85
	E	25.9	217.1		9.1	75.9	

Table 26 – RGU Module results by Non-MSU and MSU

UoS Modules		Non-MSU			MSU		
		Fail	Pass	Total	Fail	Pass	Total
COM1002 Not Sig.	**O**	8 (10.7%)	67 (89.3%)	75	2 (100%)	0 (0.0%)	14
	E	9.7	65.3		0.3	1.7	
ACS123 Not Sig.	**O**	17 (14.4%)	101 (85.6%)	118	2 (14.3%)	12 (85.7%)	14
	E	17.0	101.0		2.0	12.0	
MAS143_4 sig. p<0.05	**O**	18 (5.2%)	328 (94.8%)	346	8 (18.6%)	35 (81.4%)	43
	E	32.1	322.9		2.9	40.1	
MAS145_6 sig. p<0.05	**O**	22 (18.5%)	97 (81.5%)	119	12 (35.3%)	22 (64.7%)	34
	E	26.4	92.6		7.6	26.4	
MAS147_8 Not sig.	**O**	23 (9.1%)	229 (90.9%)	252	3 (7.5%)	37 (92.5%)	40
	E	22.4	229.6		3.6	36.4	
MAS149_50 Not sig.	**O**	53 (11.9%)	394 (88.1%)	447	8 (22.9%)	27 (77.1%)	35
	E	56.6	390.4		4.4	30.6	
Module Level 2							
MAS244 Not Sig.	**O**	35 (13.8%)	219 (86.2%)	254	7 (16.3%)	36 (83.7%)	43
	E	35.9	218.1		6.1	36.9	
MAS248 Not Sig.	**O**	33 (27.7%)	86 (72.3%)	119	11 (42.3%)	15 (57.7%)	26
	E	36.1	82.3		7.9	18.1	
MAS252 Sig. p<0.05	**O**	10 (5.1%)	186 (94.9%)	196	4 (23.5%)	13 (76.5%)	17
	E	12.9	183.1		1.1	15.9	
MAS253 Not Sig.	**O**	42 (17.6%)	197 (82.4%)	239	3 (17.6%)	14 (82.4%)	17
	E	42.0	197.0		3.0	14.0	

Table 27 – UoS Module results by Non-MSU and MSU

The results confirm that at RGU the *MSU* student performed better than the *Non-MSU* student except on the computing mathematics For module group CM2901_2 at level 2 *MSU* students statistically significantly out-performed the *Non-MSU* students, which indicates a positive longer term benefit of mathematics support.

The effect size for all three of the significant results was *moderate* and *higher* than the effect sizes of the remaining module differences.

At UoS both levels 1 and 2 modules results were better for *Non-MSU* students though the difference between the expected and observed did not rise above 4. But considering that the majority of *MSU* students began with lower mathematical ability (Section 5.1) it is important to examine improvement in the mathematical skills level by mathematics support students rather than just a comparison between MSU and Non-MSU students' performance. The starting mathematics level of the students' needs to be considered as this shows the value added by mathematics support.

The value added to students' mathematical skills i.e. how much they (*MSU* students) have improved on their mathematical skills by the end of a year is now discussed. Using *MEQ* (Table 18 and Table 19) and *BMDT* (Table 20 and Table 21) grades as their skills at the start and the module results (Table 26 and Table 27) at the end of the study years 1 and 2 as their skills at the end, the *differences* in the scores were compared for *Non-MSU* and *MSU* students.

	Non-MSU			MSU			Variance Assumed	Tests Statistics					
Level 1	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		T	df	sig (2-tailed)	Mean Diff	Std. Error Diff	Cohen's d
CM1003	243	4.54	1.461	23	3.22	1.622	Y	4.108	264	0.000	1.322	0.322	0.9
CM1900	105	4.27	1.852	20	4.55	1.731	Y	-0.633	123	0.528	-0.283	0.447	-0.2
CM1901_2	43	4.30	1.833	19	4.89	1.100	N	-1.305	60	0.197	-0.592	0.454	-0.4
Level 2													
CM2900_1	243	4.17	1.624	85	4.19	1.107	N	-0.123	215.57	0.902	-0.020	0.159	-0.01

Table 28 - RGU Module (L1 and L2) grades summaries for the Independent-samples t-test for Non-MSU and MSU

	Non-MSU			MSU			Variance Assumed	Tests Statistics					
Level 1	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		T	df	sig (2-tailed)	Mean Diff	Std. Error Diff	Cohen's d
MAS143_4	346	67.60	17.346	43	57.73	24.247	N	2.589	47.489	0.013	9.871	3.813	0.5
MAS145_6	119	53.08	16.349	34	49.57	21.302	N	0.888	44.689	0.379	3.506	3.949	0.2
MAS147_8	252	65.00	18.524	40	65.41	19.028	Y	0.501	-0.130	0.897	-0.411	3.164	-0.02
MAS149_50	445	64.42	19.272	35	62.77	25.488	N	0.375	37.122	0.710	1.652	4.404	0.08
Level 2													
MAS244	254	58.62	20.260	43	54.12	18.252	Y	1.367	295	0.173	4.506	3.296	0.2
MAS248	119	53.96	21.500	26	47.81	22.914	Y	1.306	143	0.194	6.150	4.709	0.3
MAS252	196	63.03	16.364	17	53.41	20.208	Y	2.279	211	0.024	9.614	4.219	0.6
MAS253	239	54.96	19.331	17	52.06	14.407	Y	0.606	254	0.545	2.899	4.784	0.2

Table 29 - UoS Module (L1 and L2) marks summaries for the Independent-samples t-test for Non-MSU and MSU

	Non-MSU			MSU			Variance Assumed	Tests Statistics					
Level 1	**N1**	**Mean**	**Std. Dev.**	**N2**	**Mean**	**Std. Dev.**		**T**	**df**	**sig (2-tailed)**	**Mean Diff**	**Std. Error Diff**	**Cohen's d**
MAS143_4	346	5.00	1.312	43	4.37	1.800	N	2.827	47.707	0.005	0.628	0.283	0.5
MAS145_6	119	3.76	1.505	34	3.35	1.905	N	1.161	45.421	0.252	0.412	0.355	0.3
MAS147_8	252	4.72	1.482	40	4.62	1.547	Y	0.368	290	0.713	0.093	0.254	0.1
MAS149_50	445	4.62	1.554	35	4.31	1.906	N	0.931	37.623	0.358	0.308	0.330	0.2
Level 2													
MAS244	254	4.21	1.654	43	3.81	1.607	Y	1.467	295	0.143	0.399	0.272	0.2
MAS248	119	3.72	1.939	26	3.23	1.883	Y	1.178	143	0.241	0.492	0.418	0.3
MAS252	196	4.71	1.333	17	3.65	1.801	Y	1.801	211	0.003	1.062	0.347	0.8
MAS253	239	3.94	1.657	17	3.76	1.562	Y	0.426	254	0.670	0.177	0.414	0.1

Table 30 - UoS Module (L1 and L2) grades summaries for the Independent-samples t-test for Non-MSU and MSU

The mean differences for MSU groups' modules results and their respective *MEQ* and *BMDT* tests scores are summarised in Table 31. MEQ Mathematics A-Level grades have been given a numeric values that is A=6, B=5, C=4, D=3, E=2 and F=1, a weakness in using this method is that the grades are not evenly spaced out as are the numbers they have been assigned and the value SPSS put on these numbers. However as BMDT percentages are being used in conjunction with the MEQ grades, it was felt worth retaining because MEQ's do follow a similar pattern to the BMDT percentages. Highlighted in grey is the narrowing mathematical skills level gap by *MSU* students. For example on module MAS143_4 the *MEQ* mean difference between *Non-MSU* and *MSU* students was 0.598 (*MSU* students had 0.598 lower mean grade than the *Non-MSU* students). Then looking at the mean difference of module grades, there was a difference of 0.628, in this case the difference is larger than the starting ability difference therefore the Value Added Score (*VAS*) is negative for mathematics support. Table 31 shows the VAS with the positive scores highlighted in grey and Chart 10 gives a graphical representation of VAS in Module MAS143-44 (which has shown statistical significance).

		Differences in means				Gap reduced by MSU Students **Value Added Score**	
		Maths Ability at Start		**Maths Ability at End of L1**			
Institute	**Module**	**MEQ Grades**	**BMDT Percent ages**	**Modules Grades**	**Modules Percent ages**	**For MEQ (grades)**	**For BMDT (percentages)**
RGU	CM1003	0.620	20.692	1.322		-0.702	
	CM1900	0.157	10.922	-0.283		0.440	
	CM1901_2	0.044	2.194	-0.592		0.636	
UoS	MAS143_4	0.598	21.396	0.628	9.871	-0.030	11.525
	MAS145_6	0.576	20.122	0.412	3.506	0.164	16.616
	MAS147_8	0.461	2.316	0.093	-0.411	0.368	2.727
	MAS149_5	0.227	24.459	0.308	1.652	-0.081	22.807

Table 31 – Value added to mathematical skills level at end of Levels 1

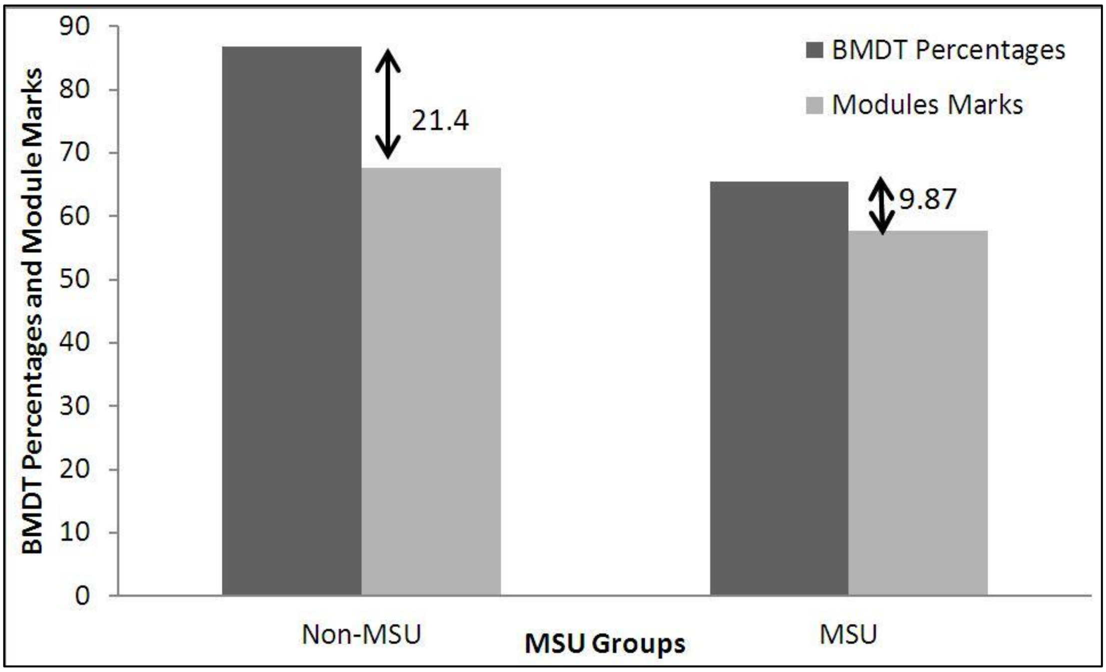


Chart 10 – Value added to mathematical skills – MAS143-44

At UoS the mean differences (Table 31) for the level 1 module results for *Non-MSU* and *MSU* are less than the mean differences in the students' mathematical skills (*MEQ* and *BMDT*) indicating the value added by mathematics support but only MAS143-44 is significant.

5.2.1 Potential performance by Non-MSU with mathematics support

Applying the value added score by mathematics support to the known *Non-MSU* shows the students at UoS who had failed to get pass marks would have benefited greatly. The actual marks and predicted mark for MAS143_4 is provided in Table 32 shows that 10 (56%) out of the 18 students who had failed could have passed had they engaged with mathematics support and improved by the 11.5 value added marks identified in the *MSU* cohort for that module. Similarly, for Modules MAS145_6, MAS147_8 and MAS149_50 (see Appendix 14) the number of students who could have benefited are 19 (95%), 8 (33%) and 46 (92%).

Actual Module Mark	VAS due to Maths support	Predicted Mark	Students
8	11.5	19.5	1
8.5	11.5	20	1
12.5	11.5	24	1
15	11.5	26.5	1
18.5	11.5	30	1
19	11.5	30.5	1
19.5	11.5	31	1
24.5	11.5	36	1
28.5	11.5	40	1
32.5	11.5	44	1
33	11.5	44.5	1
35	11.5	46.5	1
35.5	11.5	47	1
36	11.5	47.5	1
37.5	11.5	49	1
38.5	11.5	50	3
		Total Students	**18**

Non-MSU Students With predicted marks After maths support		
Fails	8	44%
Passes	10	56%

Actual MSU Students Summary		
Fails	8	19%
Passes	35	81%

Table 32 – MAS143_4 module marks

Therefore over one year there has been a greater improvement in mathematical skills for students who had made use of mathematics support and based on the predicted marks above potentially greater improvement by *Non-MSU* students had they engaged with mathematics support.

For the results of level 2 modules the differences had increased with differences of 4.506, 6.150, 9.614 and 2.899 for the four modules. The mean for the difference in modules 2 was 5.792 whereas the mean for the modules 1 was 3.655 indicating a lesser positive effect of mathematics support in year 2 performance, this result is different to that of the RGU dataset where there was a slightly better result for *MSU* students in year 2 as well as year 1. However the effect size for the RGU analysis was small and does not provide a reliable result due to age and numerous decodings. The effect size of the UoS significant module results (MAS143_4 and MAS252) was *moderate* and more reliable. Thus without further work the longer term positive effects of mathematics support is seen but cannot be confirmed in this analysis. However, positive effects have been noted in other research (Patel 2001; Patel and Little 2006; Mac an Bhaird, Morgan *et al,.* 2009; Patel and Rossiter 2009) so there is no reason not to pursue this line of research further.

In a previous joint study by Patel and Little (2006) the module results were analysed as individual events and a significant result was obtained showing a better result, 4% more passes for mathematics support students which translated to 76 positive module results. The RGU dataset used in this study is a subset of this data and as expected the overall module results events (arranged in a non-longitudinal manner) gave similar results (highlighted in Table 33) as the previous study ($p<0.05$) with a better result for mathematics support with 6.2% more passes (93.3%-87.1%) translating to 8 (4.9%) more students passing within a cohort of 164.

5.2.2 Performance on Level 1 and Level 2 modules

A further breakdown by module levels 1 and 2 indicated a positive result with more increased passes than expected (by 12.9%) for level 2 and equal performance at level 1. Considering only these factors mathematics support has helped students who started with lesser mathematical skills to perform as well as the control group who started with higher mathematical skills, and at level 2 using mathematics support has helped students to perform better than the control group. This is consistent as performance does naturally improve with the use of additional sources of learning and information. The magnitude of the difference (greater than 5%) was only reached by mathematics support users in the fail group at level 2 where there were 8.2 less fails for mathematics support students which was 9.6% of the within group total.

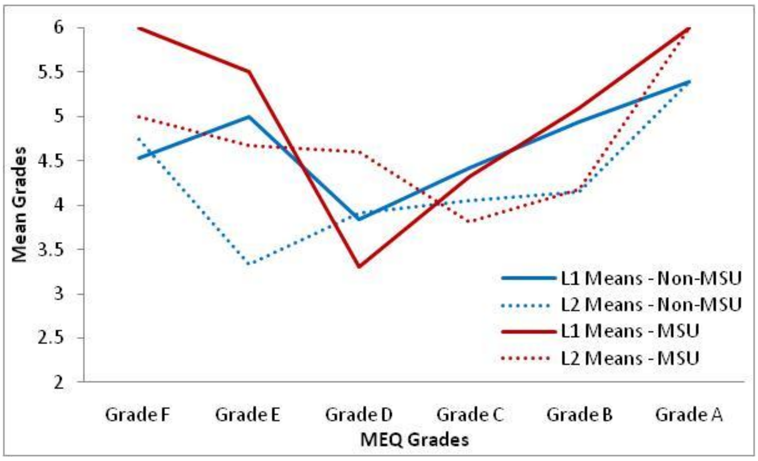


Chart 11 – RGU: MEQ grades by L1 and L2 module means for MSU

The analyses of UoS module results for *Non-MSU* and *MSU* were based on usage during the relevant year i.e. usage in study year 1 for level 1 modules and usage in year two for level 2 modules. These have been summarised in Table 35 as the differences in mark means. Only the modules that had enough cases with *BMDT* results have been included.

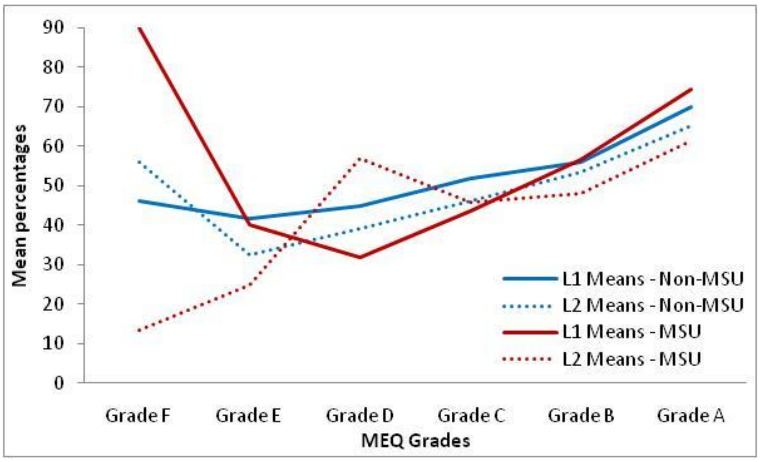


Chart 12 – UoS: MEQ grades by L1 and L2 module means for MSU

For both RGU and UoS, students who only used mathematics support in the first year performed better in the second year than those who continued mathematics support usage in second year. However, the results for both institutes are not statistically significant when using only the students for whom year 2 module results are known.

RGU Modules Overall		Non-MSU			MSU			Total		
		Fail	Pass	Total	Fail	Pass	Total	Fail	Pass	Total
Overall Module Results	Observed	87 (12.9%)	586 (87.1%)	673	11 (6.7%)	153 (93.3%)	164	98 (11.7%)	739 (88.3%)	837
Significant p<0.05	Expected	78.8	594.2		19.2	144.8				
Level 1 Module Results	Observed	49 (11.5%)	376 (88.5%)	425	9 (11.4%)	70 (88.6%)	79	58 (11.5%)	446 (88.5%)	504
Not significant p=0.99	Expected	48.9	376.1		9.1	69.9				
Level 2 Module Results	Observed	38 (15.3%)	210 (84.7%)	248	2 (2.4%)	83 (97.6%)	85	40 (12.0%)	293 (88.0%)	333
Significant p<0.05	Expected	29.8	218.2		10.2	74.8				

Table 33 – Chi-square for RGU module results events by mathematics support students for overall, Level 1 and Level 2 modules – Non-longitudal

	MSU in Year 1 and 2			MSU in Year 1 only			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	Df	sig (2-tailed)	Mean Difference	Std. Error Difference	
MEQ	47	4.53	0.747	25	3.88	0.971	Y	3.169	70	0.002	0.652	0.206	0.794
Level 1 Modules	19	4.84	1.167	16	5.19	0.834	Y	-0.989	33	0.330	-0.345	0.349	-0.350
Level 2 Modules	52	4.15	1.144	33	4.24	1.062	Y	-0.358	83	0.722	-0.089	0.248	-0.082

Table 34 – MEQ, Level 1 and Level 2 module grades summaries for MSU in years 1 and 2 and MSU in year 1 student groups for RGU

	MSU in Year 1 and 2			MSU in Year 1 only			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		t	Df	sig (2-tailed)	Mean Difference	Std. Error Difference	
MEQ	63	103.81	18.87	21	105.71	16.90	Y	-0.411	82	0.682	-1.905	4.640	-0.104
Level 1 Modules	63	65.20	18.88	21	63.79	16.55	Y	0.306	82	0.761	1.413	4.621	0.078
Level 2 Modules	63	52.86	19.03	21	57.57	15.43	Y	-1.027	82	0.307	-4.714	4.590	-0.262

Table 35 – MEQ, Level 1 and Level 2 module marks summaries for MSU in years 1 and 2 and MSU in year 1 student groups for UoS

For RGU, the students who used mathematics support in year 1 only had significantly lower entry qualifications but as with the UoS they performed better than those who used mathematics support in both years indicating that mathematics support may be at its most useful as year 1 support and that sustained used in year 2 is not necessary for better performance. This is not an unexpected result as mathematics support at RGU and UoS is intended usually to help students 'catch-up' with respect to mathematical skills and used well should be sufficient in the first year.

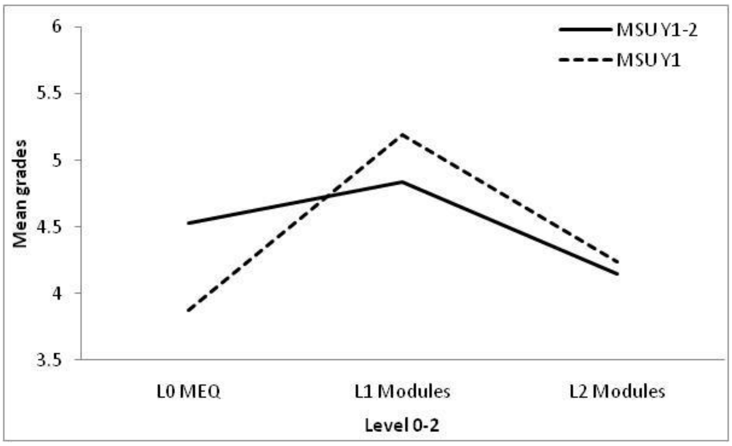


Chart 13 – RGU: modules means at L0, L1 and L2 for MSUY1-2 and MSUY1

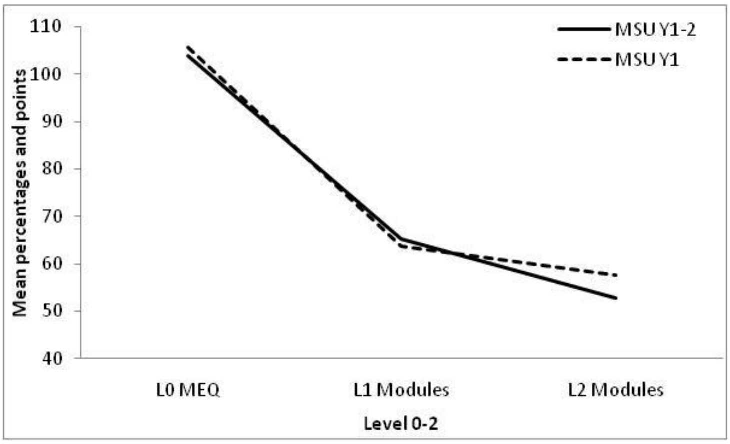


Chart 14 – UoS: modules means at L0, L1 and L2 for MSUY1-2 and MSUY1

5.2.3 Analysis of attitudes towards mathematics

Chi-squares test of independence analysis of the Attitudes by Non-MSU and MSU gave the results provided in Table 36, Table 37 and Table 38. Highlighted in grey are the positive outcomes for mathematics support; 'Good' confidence, enjoying mathematics and fair past experience all lead to more engagement with mathematics support.

Confidence[7] $\chi^2=14.571$ df=4 sig $p<0.05$	Likert Scale	O/E	MSU Group		Total
			Non-MSU	MSU	
	Poor	O	17 (3.3%)	2 (2.2%)	19 (3.1%)
		E	16.1	2.9	
	Less than Adequate	O	109 (21.2%)	14 (15.4%)	123 (20.4%)
		E	104.5	18.5	
	Adequate	O	245 (47.8%)	46 (50.5%)	291 (48.2%)
		E	247.2	43.8	
	Good	O	93 (18.1%)	28 (30.8%)	121 (20.0%)
		E	102.8	18.2	
	Exceptional	O	49 (9.6%)	1 (1.1%)	50 (8.3%)
		E	42.5	7.5	
	Total		**513 (100%)**	**91 (100%)**	**604 (100%)**

Table 36 – Attitude 1 scores for Non-MSU and MSU – RGU

Liking for maths[8] $\chi^2=16.464$ df=4 Sig $p<0.05$	Likert Scale	O/E	MSU Groups		Total
			Non-MSU	MSU	
	Don't Find Maths Interesting	O	17 (3.3%)	1 (1.1%)	18 (3.0%)
		E	15.3	2.7	
	Don't Find Maths Enjoyable	O	93 (18.3%)	15 (16.9%)	108 (18.1%)
		E	91.9	16.1	
	Indifferent	O	218 (42.9%)	36 (40.4%)	254 (42.5%)
		E	216.1	37.9	
	Find Maths Enjoyable	O	100 (19.7%)	31 (34.8%)	131 (21.9%)
		E	111.5	19.5	
	Find Maths Interesting	O	80 (15.7%)	6 (6.7%)	86 (14.4%)
		E	73.2	12.8	
	Total		**508 (100%)**	**89 (100%)**	**597 (100%)**

Table 37 – Attitude 2 scores for Non-MSU and MSU - RGU

[7] 1 cell (10.0%) has expected count less than 5. The minimum expected count is 2.86.
[8] 1 cell (10.0%) has expected count less than 5. The minimum expected count is 2.68.

	Likert Scale	O/E	MSU Groups: Non-MSU	MSU Groups: MSU	Total
Past Experience[9] $\chi^2=10.827$ df=4 Sig $p<0.05$	Very Bad	O	7 (1.4%)	1 (1.1%)	8 (1.3%)
		E	6.8	1.2	
	Bad	O	40 (7.9%)	6 (6.9%)	46 (7.7%)
		E	39.3	6.7	
	Fair	O	174 (34.3%)	42 (48.3%)	216 (36.4%)
		E	184.4	31.6	
	Good	O	215 (42.4%)	35 (40.2%)	250 (42.1%)
		E	213.4	36.6	
	Excellent	O	71 (14.0%)	3 (3.4%)	74 (12.5%)
		E	63.2	10.8	
	Total		**507 (100%)**	**87 (100%)**	**594 (100%)**

Table 38 – Attitude 3 scores for Non-MSU and MSU - RGU

A deeper analysis using two-way ANOVA for each of the *Attitudes-1-3* by mathematics entry qualifications and mathematics support visits reveals that students with low mathematics entry qualifications grades and high single visits had *Poor, Less than adequate and Adequate* Confidence (Table 39), *Don't find maths interesting, Enjoyable or Indifferent* Liking for mathematics (Table 41) and *Very bad, Bad or Fair* Experience of mathematics teaching (Table 43).

The MEQ grades were put into categories to allow for a reasonable numbers of cases in the breakdown for MEQ Grades and MSU Visits categories. The categories comprise of Grades A-B = High, Grade C = Medium and Grades D-F = Low.

MEQ Grades	Attitude 1 – Count	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Poor, Less than adequate or Adequate	114	4	4	7	129
	Exceptional or Good	63	0	5	10	78
Medium	Poor Less than adequate or adequate	154	7	8	17	207
	Exceptional or Good	50	2	3	6	61
Low	Poor, Less than adequate or adequate	103	6	10	9	128
	Exceptional or Good	29	1	1	1	32

Table 39 – Count of Level 1 modules of RGU students Attitude-1 confidence towards mathematics by MEQ's and MSU Visits

[9] 1 cell (10.0%) has expected count less than 5. The minimum expected count is 1.17.

MEQ Grades	Attitude 1 – Module Means	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Poor, Less than adequate or Adequate	4.94	6.00	4.50	4.33	4.91
	Exceptional or Good	5.17		4.00	5.67	5.18
Medium	Poor, Less than adequate or adequate	4.60	5.50	4.33	4.67	4.63
	Exceptional or Good	4.16		5.00	4.00	4.19
Low	Poor, Less than adequate or adequate	4.24	4.60	4.10	4.00	4.23
	Exceptional or Good	3.69			3.00	3.64

Table 40 – Means of Level 1 modules of RGU students Attitude-1 confidence towards mathematics by MEQ's and MSU Visits

Table 40 shows the mean grades of level 1 module by *MEQ* Grade groups and *Attitude-1* with corresponding profile plots (Charts 15-17). The plots show that students with weaker confidence performed better with repeat use of mathematics. Surprisingly, the greater the self-perceived confidence in mathematical ability the poorer the module grades, and use of *MSU* does not give a different pattern. The students with low self-perceived confidence in ability perform well. So the construct self-perceived confidence in mathematical ability is not giving any significant results though the pattern appears to contradict the self-perceived confidence of students. However, this statement is made with caution because of the low numbers in the groups.

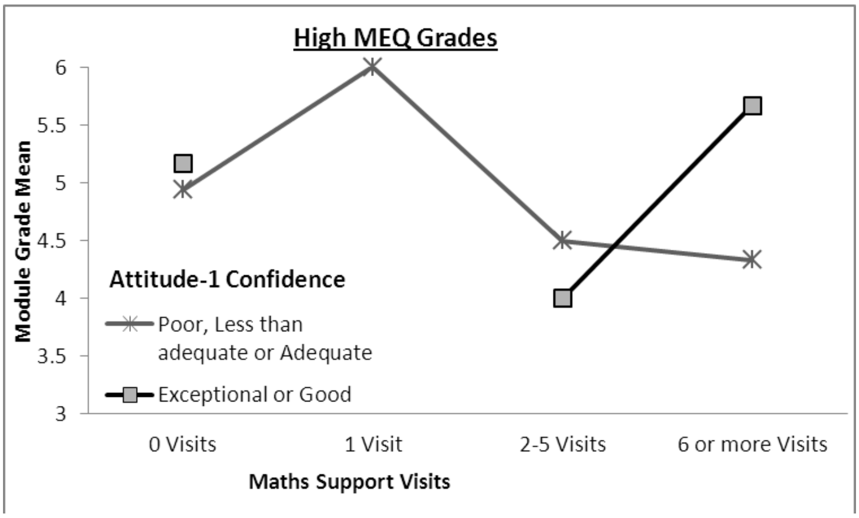


Chart 15 – Attitude-1 by module means for high MEQ grades - RGU

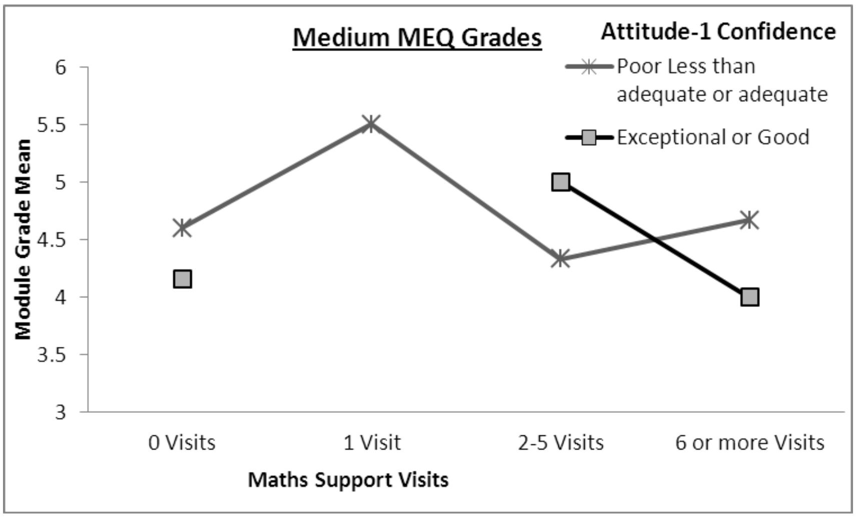


Chart 16 – Attitude-1 by module means for medium MEQ grades – RGU

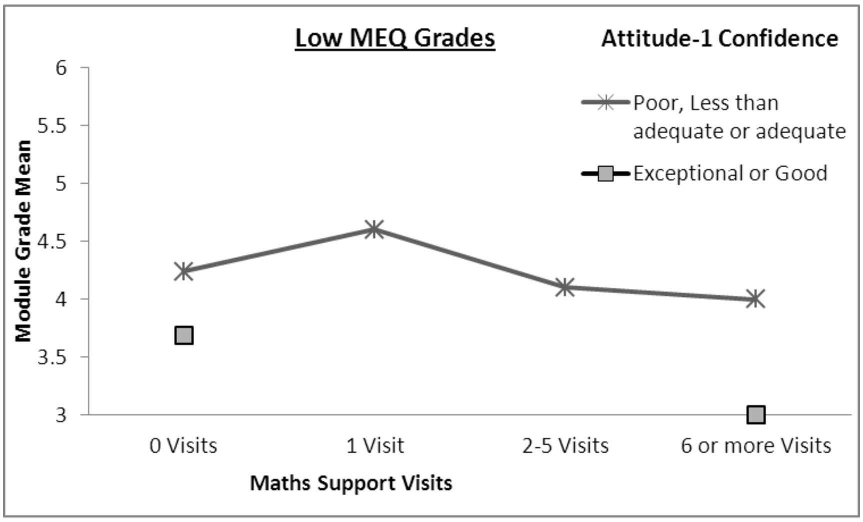


Chart 17 – Attitude-1 by module means for low MEQ grades - RGU

MEQ Grades	Attitude 2 – Count	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Don't find maths interesting, enjoyable or am indifferent	117	3	2	7	129
	Find maths interesting or enjoyable	59	1	7	10	77
Medium	Don't find maths interesting, enjoyable or am indifferent	129	4	9	8	152
	Find maths interesting or enjoyable	75	6	10	9	128
Low	Don't find maths interesting, enjoyable or am indifferent	82	5	8	4	99
	Find maths interesting or enjoyable	46	2	1	6	55

Table 41 – Count of Level 1 modules of RGU students Attitude-2 liking for mathematics by MEQ's and MSU Visits

MEQ Grades	Attitude 2 – Module Means	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Don't find maths interesting, enjoyable or am indifferent	5.02	6.00	4.00	5.00	5.02
	Find maths interesting or enjoyable	5.00		4.50	5.00	4.97
Medium	Don't find maths interesting, enjoyable or am indifferent	4.46	5.50	4.33	4.67	4.49
	Find maths interesting or enjoyable	4.56	5.50	5.00	4.00	4.60
Low	Don't find maths interesting, enjoyable or am indifferent	4.09	4.50	4.00	3.00	4.09
	Find maths interesting or enjoyable	4.38	5.00	6.00	4.00	4.39

Table 42 – Means of Level 1 modules of RGU students Attitude-2 liking for mathematics by MEQ's and MSU Visits

The summary of the module means for *Attitude-2* is provided in Table 42 with corresponding profile plots in Chart 18, Chart 19 and Chart 20. A similar pattern can be seen for High graders with Medium graders' *Liking for mathematics* not really making a big difference to performance. The students with low grades performed better if their *Liking for mathematics* was high and they also benefited from mathematics support.

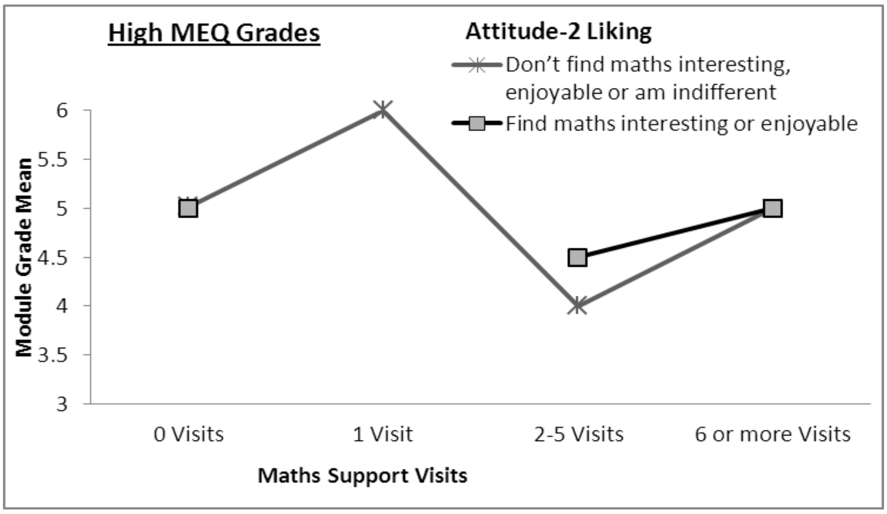


Chart 18 – Attitude-2 by module means for high MEQ grades - RGU

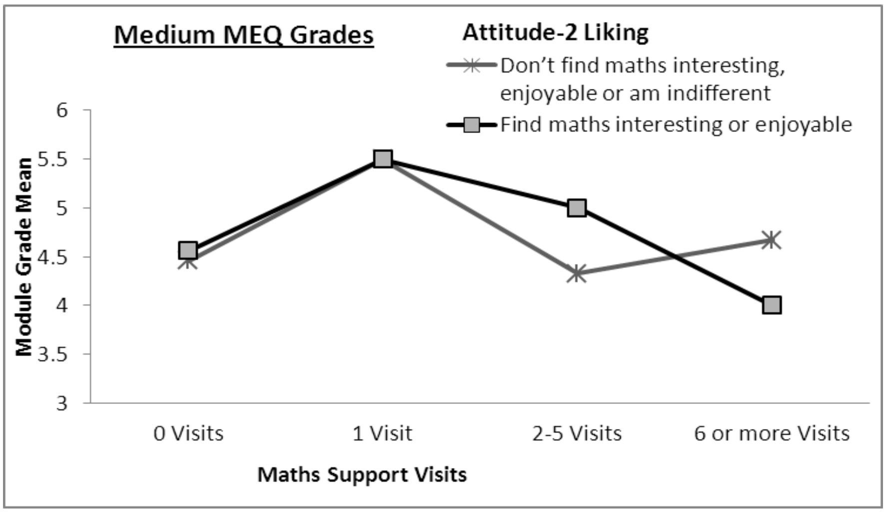


Chart 19 – Attitude-2 by module means for medium MEQ grades - RGU

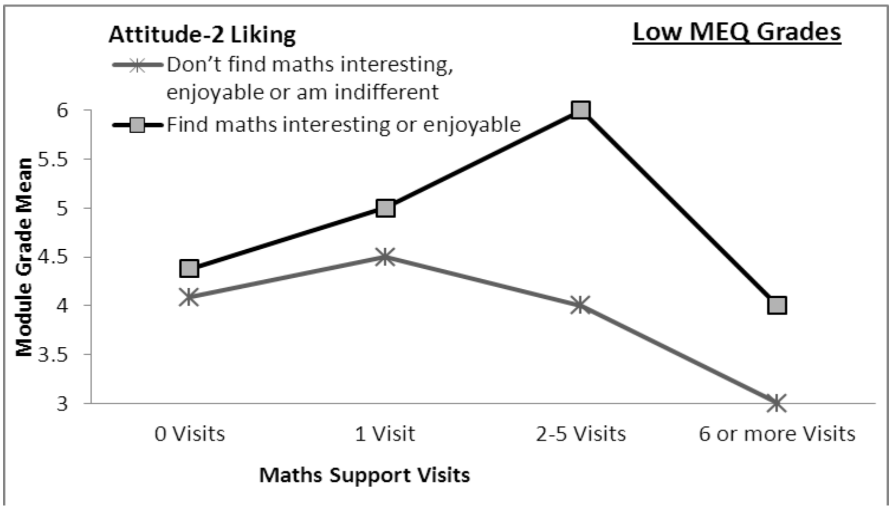


Chart 20 – Attitude-2 by module means for low MEQ grades – RGU

MEQ Grades	Attitude 3 – Count	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Very bad, Bad or Fair	47	1	2	7	57
	Good or Excellent	128	3	7	10	148
Medium	Very bad, Bad or Fair	95	5	7	8	115
	Good or Excellent	108	4	4	5	121
Low	Very bad, Bad or Fair	79	4	6	9	98
	Good or Excellent	50	2	2	1	55

Table 43 – Count of Level 1 modules of RGU students Attitude-3 past experience of mathematics by MEQ's and MSU Visits

MEQ Grades	Attitude 3 – Module Means	0 Visits	1 Visit	2-5 Visits	6 or more Visits	Total
High	Very bad, Bad or Fair	5.16	6.00		3.50	5.05
	Good or Excellent	5.00		4.33	5.75	5.02
Medium	Very bad, Bad or Fair	4.23	5.33	5.00	5.00	4.36
	Good or Excellent	4.73	6.00	4.00	4.00	4.70
Low	Very bad, Bad or Fair	3.90	4.67	4.40	4.00	3.98
	Good or Excellent	4.75	6.00	4.00	3.00	4.69

Table 44 – Means of Level 1 modules of RGU students Attitude-3 past experience of mathematics by MEQ's and MSU Visits

The summary of the module means for *Attitude-3* in Table 44 together with profile plots is presented in Charts 21-23. The pattern for High graders is not easy to see but Medium and Low graders performed better with a positive *Past experience* though continual mathematics support usage has not led to better performance for this group of students.

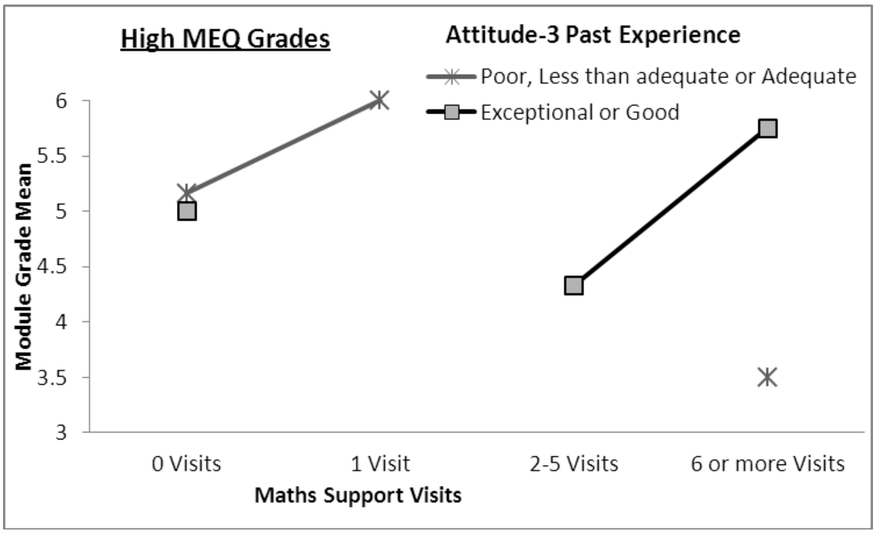


Chart 21 – Attitude-3 by module means for high MEQ grades - RGU

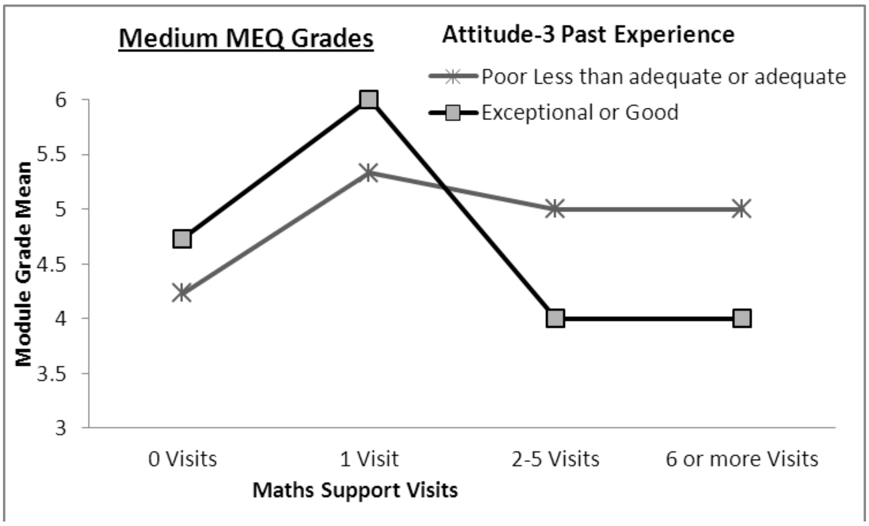


Chart 22 – Attitude-3 by module means for medium MEQ grades – RGU

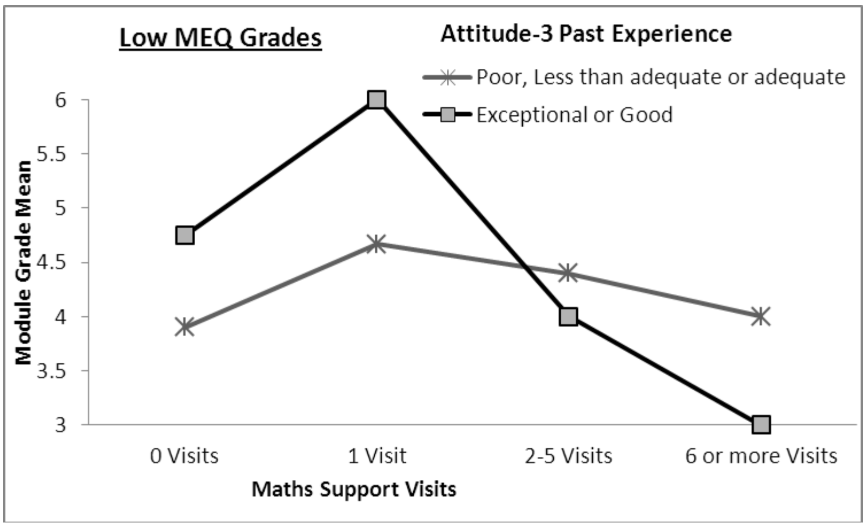


Chart 23 – Attitude-3 by module means for low MEQ grades - RGU

Confidence in mathematics, a liking for and good past experiences of mathematics were good motivators for students making repeat visits for mathematics support. A positive correlation was found between a positive attitude towards mathematics (as measured by confidence and enjoyment scales) and frequency of mathematics support usage.

The study by Liston and O' Donoghue (2009) is more detailed in gathering data for analysis of students' *Attitudes* to mathematics and how these can affect learning. The analysis of the *Attitudes* in this study is limited but will lead to recommendations for further study.

The analysis of the RGU dataset has shown that students who used mathematics support tended to have a lower mathematical ability evidenced by students' mathematics entry qualifications and mathematics diagnostic test percentage scores. The analysis of students' attitudes towards mathematics showed that the students' self-perceived *confidence* is not correlated with performance *Liking for mathematics* provided motivation for engaging with mathematics help. Positive *past experience* with mathematics has led to some improved performance but the student numbers in all these groups for *MSU* are too low to draw serious conclusions and are not factored into the overall model.

A similar analysis was carried out on the UoS data for the 37 results on students' *Attitudes* but this is not presented here due to the low numbers.

An essential element of the successful implementation of mathematics support has been the recognition of the significance of entry qualifications and the tailoring of mathematics support to suit. Taking account of students' prior knowledge and experience of mathematical skills provides a good starting place for addressing the mathematical difficulties some students face. Thus, as stated earlier, *MEQ* points and *BMDT* percentages are important variables in this research.

5.2.4 Regression analysis - RGU

The mathematics module results have been gathered for study years 1 and 2 because mathematics support is mainly targeted at these levels (although generally it is not restricted to these). The results of an examination of the changes in students' mathematical ability at the end of years 1 and 2 to see whether there was a significant difference in the scores for *Non-MSU* or *MSU* are detailed below.

The *MSU* students at RGU managed to perform to an equal level to the *Non-MSU* students on level 1 modules and actually out performed them on level 2 modules.

There is some correlation between *BMDT* and performance on modules - see Chart 24 (bear in mind the results for RGU do not contain full sets of marks for the modules) and similar results have also been found by Lee, Harrison *et al.* (2008) who went on to use regression to define a prediction model for module results.

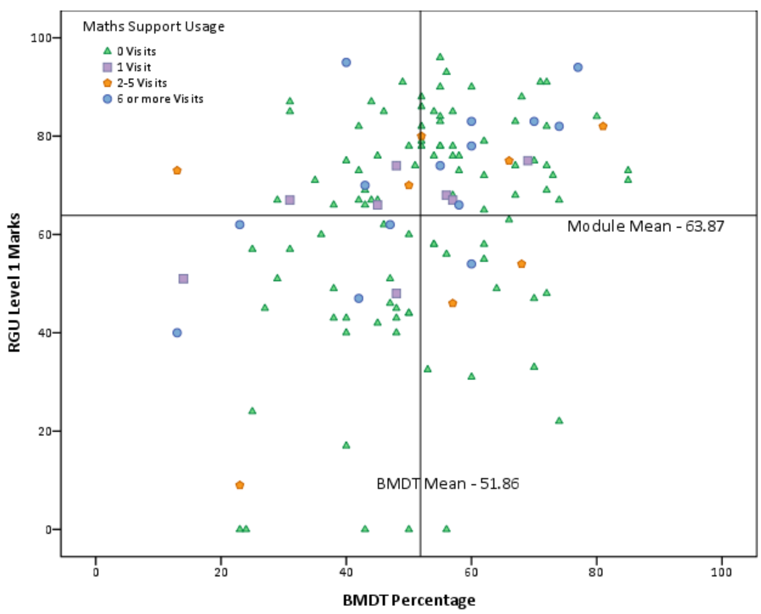


Chart 24 – Scattergraph of BMDT by Level 1 marks for RGU

Module grades were taken as the dependent variable and *BMDT* percentage as the independent variable in the analysis. Independent samples t-tests were also tried on *MEQ* and *Attitudes 1-3* but the results gave no consistent patterns and hence not included in the final model. Standardised (around the means for each Institute) *BMDT* scores were used to enable application of the model to the UoS data to measure its predictive capability. The results were significant ($p<0.05$) for level 1 module grades (306 cases).

There is a reasonable correlation (more than 0.3) between *BMDT* and Level 1 module grades (0.325). The multicollinearity of the independent variable was deemed acceptable using the Tolerance and VIF values one 1 and 1 which are within the thresholds of not less than 0.10 and not greater than 10 respectively (Pallant 2005).

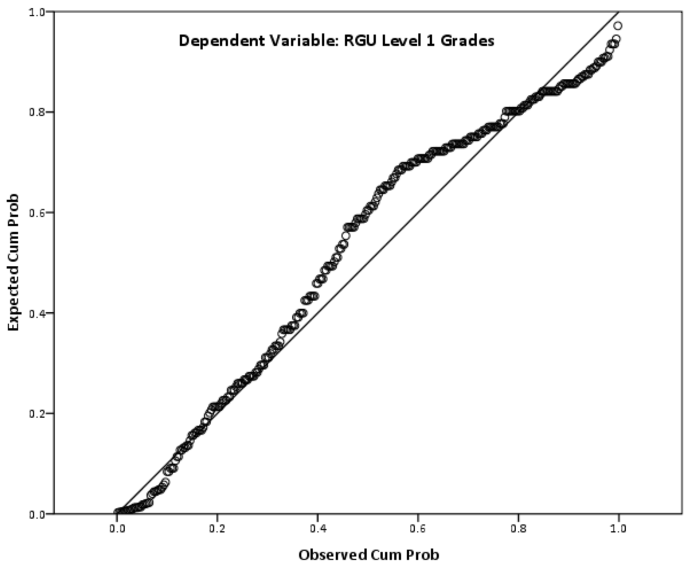


Chart 25 – Normal P-P plot of regression standardised residual – RGU

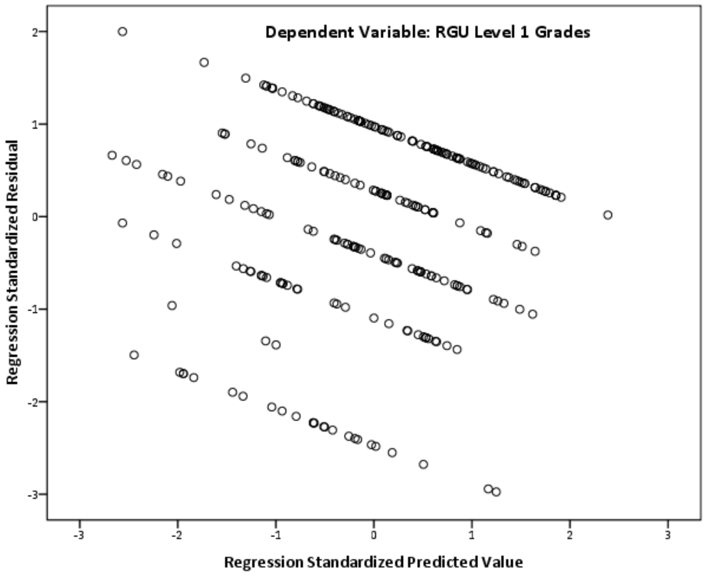


Chart 26 – Scattergraph of regression standardised value – RGU

The Normal Probability and the Residuals Scattergraph plots for the regression (charts 25 and 26) suggest no major deviations from normality, the former forming a reasonable diagonal line and the latter a cluster around 0. The Scattergraph (chart 26) reveals no possible outlier (less than -3.3 or more than 3.3).

The R^2 in this model is 0.105, with an adjusted R^2 of 0.102, the similarity implying a good model and meaning 10.5% of the variance in the dependent variable is explained by *BMDT* percentage in the model giving the following regression model for this analysis.

$Y_{RGU\_L1} = 4.603 + 0.510(BMDT)$

Equation 4 – RGU regression model for predicting module grades with *BMDT* (standardised)

This model (Equation 4) was used on the UoS dataset to explore and develop a more accurate model. BMDT percentages have been standardised using the mean and SD and here range between (-5.2571 – 2.2790) to allow use of the model on the UoS data to consider if a general model is possible. This model predicted a mean grade for UoS level 1 of 4.6 where the actual mean was 4.4; 0.2 less than expected.

Work on the regression model for the UoS dataset (section 5.4) indicate the RGU model was not a good predictor for the UoS results.

This regression model is developed further in the following section which analyses the data collected at the UoS within the mathematics support centre and further explores the tendencies (such as usage habits) of mathematics support and diagnostics test participants. Additionally, it will consider students' Approaches to Studying *(AtS)* and their relationship with mathematics support usage and overall performance on modules.

Similar to the analysis carried out on the RGU data, performance on modules was assessed using data on module results but in the UoS data there is a fuller set of module percentages. This has allowed for t-test analysis on the module percentage results. The effectiveness of the independent variables, mathematics entry qualifications and basic mathematics diagnostic test percentages on performance for students making use of mathematics support and those not (control group) is measured. The *AtS* scores of 122 respondents are analysed to consider the effect of *AtS* on overall performance and to assess any tendencies for *MSU*.

Independent samples t-tests were used for the *MEQ's, BMDT* and module marks to examine the value added by mathematics support. The Cronbach's reliability test was used to examine the reliability and suitability of *AtS* scores for factor analysis and determinant analysis was used to examine whether mathematics support attracts certain studying approaches traits. The following provides evidence for drawing inferences about performances based on the effect of the independent variables.

The data collected for this sample was sourced through the student records database main tables, these being the student details and module results tables. These did not however capture the students who had withdrawn prior to getting module results. The only way this information could have been gathered was from the relevant engineering departments and most did not have the time or inclination to offer this information. Hence the results are limited to showing only progression on modules, not overall ratio of passes and failures including withdrawals prior to assessment on modules and for the purposes of examining effectiveness of mathematics support on performance and learning development, this much information has been considered enough.

Building on the research, students' approaches to studying were identified at UoS for two cohorts of students in order to explore a better model for predicting performance in modules. The following section examines the approaches' scales and subscales for reliability before adding to the prediction model.

5.3 Approaches to studying analysis for UoS

ASSIST+ is the augmented questionnaire based on the version of the ASSIST questionnaire used by Tait *et al* (1998) with additional questions written (for this study) to identify procedural deep and surface approaches which were identified by Case and Marshall (2004). The reason the additional questions have been introduced is to test the theory (Marton, Dall'alba *et al. 1*996) that the surface approach may be a preferred approach for learning mathematics in the earlier stages with the deep approach being a successful longer term approach.

This study has examined the changes in students' mathematical skills at the end of study years 1 and 2 (section 5.2) to determine the influence of mathematics support. In this section students' approaches to studying (*AtS*) are considered in order to characterise *MSU* students.

The following are the results of the 105 (group A) UoS pre-intervention *AtS* questionnaire responses (obtained using ASSIST+) of students at the start of their engineering degree programme, 25 (group C) of whom also completed a shorter version of the questionnaire (referred to as ASSIST+) at the end of the first semester. A further 17 (group B) *AtS* scores of second and above years of study students (ASSIST+) responses were obtained to explore differences between 1st year engineering students and 2nd and 3rd year engineering students.

The comparison of the *AtS* scores of 1st year students with 2+ year students was used to see how approaches changed over the years.

As mentioned earlier, Marton *et al.* (1996) highlighted the paradox of Chinese learners who were nurtured to memorise facts and processes who still become top academic performers. The *AtS's* of 2+ year UoS students will be used to examine if this phenomenon exists in the UK HEI setting, the assumption being that initially students will prefer a more surface approach but once these skills have been mastered they can be combined to solve applied mathematical problems and even used to develop new solutions hence eventually fostering a deeper approach to learning. Similar results would need to be seen in repeated experiments for this argument to gain strength; even then other hypotheses for the trend could not be dismissed.

The results of the questionnaires in groups A and C were used in the analysis to examine the changes that had/had not taken place in *AtS* after a Semester at UoS where students will have participated in learning via mainstream methods (e.g. lectures, tutorials and, for some, mathematics support). For the pre and post intervention comparison paired samples t-tests were used.

5.3.1 ASSIST+ scoring procedure

Students responded to the 44 approaches to studying questions by selecting one of five options on five point Likert scale items coded as follows: 5 = Agree, 4 = Agree somewhat, 3 = Neither agree nor disagree, 2 = Disagree somewhat, and 1 = Disagree.

The *sub-scale* scores are calculated by adding the individual scores together and the approaches to studying *scales* by adding the *sub-scales* together. Table 45 shows what each question and combination of questions will identify.

Approach to Studying	Sub-Scale	Q1	Q2	Q3	Q4
Deep Approach	Relating Ideas	9	18	30	41
	Seeking Meaning	4	15	25	37
	Use of Evidence	8	20	31	42
	Procedural Deep - Relating Processes	14	26	29	38
Surface Approach	Lack of Purpose	3	13	24	37
	Syllabus- Boundness	10	21	32	43
	Unrelated Memorising	7	17	28	40
	Procedural Surface - Memorising Processes	5	19	33	44
Strategic Approach	Alertness to Assessment Demands	2	12	23	35
	Organised Studying	1	11	22	34
	Time Management	6	16	27	39

Table 45 – Sub-Scales within Approaches to Studying of the ASSIST+ questionnaire

The ASSIST+ questionnaire comprises of eleven *sub-scales* nine of which are from the original ASSIST questionnaire. Each *subscale* contains 4 items. *Procedural Deep – relating processes* and *Procedural Surface - memorising processes* are new *sub-scales* added to improve matching of approaches to studying in a mathematics discipline setting. The new *subscales* are placed within the *deep* and *surface scales* respectively to examine the null hypothesis that they do not belong within the *scales* but are separate scales.

5.3.2 Reliability and principal components analysis on AtS scales and sub-scales

The ASSIST+ items were examined for inter-item reliabilities using Cronbach's α, Table 46 gives a summary of the scores.

Approach to Studying	**Cronbach's α**	**Reliable**
Deep Approach	**0.880**	**Y**
Relating Ideas	0.736	Y
Seeking Meaning	0.703	Y
Use of Evidence	0.557	Accepted
Relating Processes – PD	0.659	Accepted
Surface Approach	**0.607**	**Accepted**
Lack of Purpose	0.696	Accepted
Syllabus- Boundness	0.563	Accepted
Unrelated Memorising	0.440	N
Memorising Processes – PS	0.211	N
Strategic Approach	**0.777**	**Y**
Alertness to Assessment Demands	0.483	N
Organised Studying	0.567	Accepted
Time Management	0.715	Y

Table 46 - Reliance of scales and sub-scales of Approaches of Studying

The three approaches to studying *(Deep, Surface* and *Strategic*) scales were subjected to principal components analysis using SPSS. A limitation, of the study in relation to the latter method is the number of questionnaire responses (122). The recommended number for this type of analysis is a minimum of 150 (Tabachnik and Fidell 1996). This issue can be addressed in future work through a further analysis with at least the recommended number of cases.

Prior to performing principle components analysis the suitability of data for factor analysis was assessed and the sub-scales found to be weak, the *Unrelated-memorising*, *Memorising-processes* (new *Procedural surface sub-scale*) and *Alertness-to-assessment-demands* were excluded.

Table 46 gives the Cronbach's α and correlations within the scales after the sub-scales with weak scores were removed, namely; *Unrelated-memorising, Memorising-processing (procedural surface)* and *Alertness-to-assessment-demands* have low alpha scores of 0.440, 0.211 and 0.483 respectively, much lower than the recommended Cronbach's α>0.7 and were therefore deemed not reliable and not included in the factor analysis. However, *the sub-scales* just below the scores of 0.6 for *Use-of-Evidence*, *Syllabus-boundness* and *Organised-studying* have been retained because removal of them would not leave enough *sub-scales* for the *Surface* and *Strategic scales* to be examined.

Approach to Studying	**Cronbach's α**
Deep Approach	**0.880**
Relating Ideas	0.736
Seeking Meaning	0.703
Use of Evidence	0.557
Relating Processes – PD	0.659
Surface Approach	**0.627**
Lack of Purpose	0.696
Syllabus- Boundness	0.563
Strategic Approach	**0.794**
Organised Studying	0.567
Time Management	0.715

Table 47 – Updated reliance of scales and sub-scales of Approaches of Studying

The Cronbach's α for the accepted eight *sub-scales* suitable for factor analysis are provided in Table 47. Inspection of the correlation matrix (Table 48) revealed the presence of many coefficients of 0.3 and above. The Kaiser-Mayer-Oklin (KMO) value was 0.744, which exceeds the recommended value of KMO>0.6, and the Bartlett's Test of Sphericity (Pallant 2005) reached statistical significance χ^2=356.364 P<0.05, supporting the factorability of the correlation matrix. Only the loadings for the *sub-scales* greater than 0.3 are provided in the table below and it can be seen that the only *sub-scales* with a lack of appropriate loading for this sample were those in the *Surface approach scales*.

	DP-RI[10]	DP-SM	DP-UE	DP-PRP	SR-LP	SR-SB	ST-OS
Deep-Relating Ideas							
Deep-Seeking Meaning	0.672						
Deep-Use of Evidence	0.651	0.605					
Deep-Procedural Relating Processes	0.542	0.608	0.589				
Surface-Lack of Purpose							
Surface-Syllabus Boundness							
Strategic- Organised Studying		0.384		0.378			
Strategic-Time Management				0.315			0.687

Table 48 – Correlation matrix of exploratory factor analysis on sub-scales of Approaches of Studying

The new *sub-scale Relating-processes* based on the work by Case and Marshall (2004) has a strong loading towards the *Deep approach scale* (Table 48 giving overall summary). *Time management* has a reasonably acceptable loading in the *Deep approach* and *Syllabus-Boundness* has a negative loading in the *Deep approach*.

Approach to Studying	Cronbach's α	Component 1	Component 2	Component 3
Deep Approach	**0.880**			
Seeking Meaning	0.703	0.833		
Relating Processes - PD	0.659	0.821		
Use of Evidence	0.557	0.764	-0.373	
Relating Ideas	0.736	0.759	-0.447	
Strategic Approach	**0.794**			
Time Management	0.715	0.415	0.811	
Organised Studying	0.567	0.595	0.651	
Surface Approach	**0.627**			
Lack of Purpose	0.696			0.880
Syllabus- Boundness	0.563	-0.427		0.422

Table 49 – Principal component analysis for 3 components

[10] DP-RI=Deep-Relating Ideas, DP-SM=Deep-Seeking Meaning, DP-UE=Deep-Use of Evidence, DP-PRP=Deep-Procedural Relating processes, SR-LP=Surface-Lack of Purpose, SR-SB=Surface-Syllabus Boundness, ST-OS=Strategic- Organised Studying and ST-TM=Strategic-Time Management

Principal components analysis revealed the presence of three components (Table 49) with eigenvalues exceeding 1. These components explained 40.8%, 19.0% and 13.4% of the variance respectively (see Table 73 in Appendix 17). An inspection of the scree plot Figure 10 revealed a break after the 5th component. Using the Catell B IQ test (1966) scree test interpretation it was decided to retain the 3 components for further investigation and factor analysis.

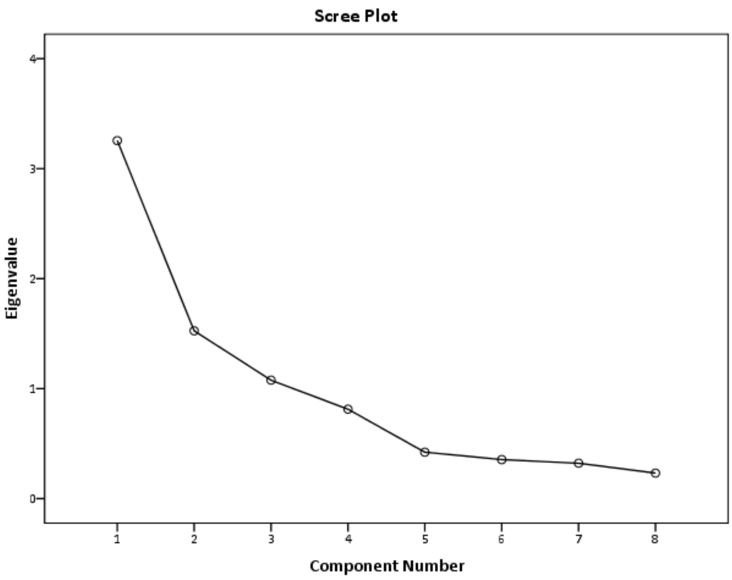


Figure 10 – Scree plot for approaches to studying scales and sub-scales

To aid in the interpretation of these three components, Varimax rotation was performed. The rotated solution revealed the presence of a simple structure (Thurston 1947). All three components showed a number of strong loadings (Table 49) for all variables, loading substantially on the three components. The components solution explained a total of 73.2% of the variance, with component-1 contributing 35.5%, component-2 contributing 22.6% and component-3 15.1% (see Table 74 in Appendix 17).

The interpretation of the components was consistent with previous research (Centre for Research on Learning and Instruction 1997) on approaches to studying scales with deep and procedural deep items loading strongly on component-1 and strategic on component-2, indicating that separating out the scales is complex as it involves individuals' motivation, intention and strategy. The results of the analysis were further strengthened as the component correlations of 0.430 (Deep/Strategic), -0.235 (Deep/Surface) and -0.200 (Surface/Strategic) showed a very weak correlation between the components.

Approach to Studying	Cronbach's α	Component 1	Component 2	Component 3
Deep Approach	**0.880**			
Relating Ideas	0.736	0.874		
Use of Evidence	0.557	0.862		
Seeking Meaning	0.703	0.834		
Relating Processes - PD	0.659	0.723	0.309	
Strategic Approach	**0.794**			
Time Management	0.715		0.915	
Organised Studying	0.567		0.886	
Surface Approach	**0.627**			
Lack of Purpose	0.696			0.908
Syllabus- Boundness	0.563			0.537

Table 50 – Principal component analysis for 3 components – rotation method varimax

The result of this clustering analysis (Table 50) supports the use of *Deep*, *Strategic* and *Surface* approaches as separate *scales*, although the overlap with *sub-scales Relating-processes* with a small but reasonable loading on component-2 leads to the question of whether this overlap (also in the right direction – towards the *Strategic* approach) is enough to separate out as a separate *scale*.

The strong loadings for the *scales* are summarised thus:

- Deep approach (component-1) – Relating-ideas, Use-of-evidence, Seeking-meaning and Procedural - Relating-processes,
- Surface approach (component-3) – Lack-of-purpose and Syllabus-boundness.
- Strategic approach (component-2) – Time-management and Organised-studying

For the reliable *AtS* scales and subscales identified above, the students' mathematical skills was considered to provide a fuller profile of the students with particular *AtS* scores.

In order to explore the relationship with *MEQ*s and students' high preference for a particular approach the *AtS* scores were divided into High or Low, the threshold being the mean of the approaches' scales. The means for Deep, Surface and Strategic being 15.4, 10.5 and 14.0, thus scores equal to and above the mean being High and the remaining Low.

The chi-square results for the 3 scales were not significant but are nevertheless summarised in Table 51, Table 52 and Table 53. Medium *MEQ* grades attracted a proportionally similar spread of Deep, Surface and Strategic students. There were proportionally less Surface students for High *MEQ* grades and more surface students for Low *MEQ* grades and Deep and Strategic had very similar breakdown. Chart 27 provides a graphical representation of these differences.

			Deep Approach		
	MEQ Grades		**High**	**Low**	**Total**
χ^2=3.941 df=2 Not sig p=0.139	High Grades	Observed	65 (60.7%)	13 (86.7%)	78 (63.9%)
		Expected	68.4	9.6	
	Medium Grades	Observed	37 (34.6%)	2 (13.3%)	39 (32.0%)
		Expected	34.2	4.8	
	Low Grades	Observed	5 (4.7%)	0 (0.0%)	5 (4.1%)
		Expected	4.4	0.6	
	Total		**107 (100%)**	**15 (100%)**	**122 (100%)**

Table 51 – Deep approach to studying by MEQ Grades

	MEQ Grades		Surface Approach High	Surface Approach Low	Total
χ^2=4.351 df=2 Not sig p=0.114	High Grades	Observed	22 (57.9%)	56 (66.7%)	78 (63.9%)
		Expected	24.3	53.7	
	Medium Grades	Observed	16 (42.1%)	23 (27.4%)	39 (32.0%)
		Expected	12.1	26.9	
	Low Grades	Observed	5 (6.0%)	0 (0.0%)	5 (4.1%)
		Expected	3.4	1.6	
	Total		**38 (100%)**	**84 (100%)**	**122 (100%)**

Table 52 – Surface approach to studying by MEQ Grades

	MEQ Grades		Strategic Approach High	Strategic Approach Low	Total
χ^2=3.314 df=2 Not sig p=0.191	High Grades	Observed	59 (64.8%)	19 (61.3%)	78 (63.9%)
		Expected	58.2	19.8	
	Medium Grades	Observed	30 (33.0%)	9 (29.0%)	39 (32.0%)
		Expected	29.1	9.9	
	Low Grades	Observed	2 (2.2%)	3 (9.7%)	5 (4.1%)
		Expected	3.7	1.3	
	Total		**91 (100%)**	**31 (100%)**	**122 (100%)**

Table 53 – Strategic approach to studying by MEQ Grades

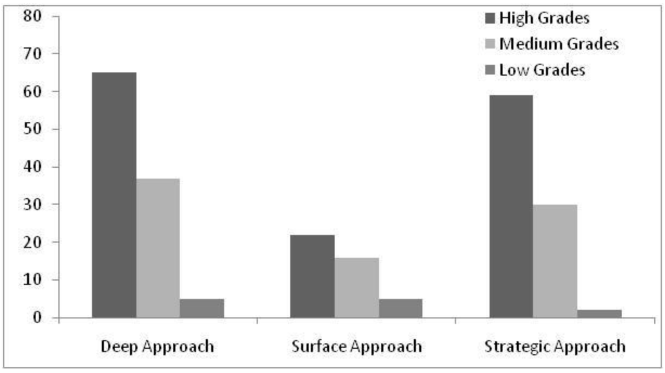


Chart 27 – AtS preferences by MEQ grades

The groups of students *with more than expected* in the *MEQ* grade groups with high *Deep Approach* and high *Surface Approach* preferences had medium grades (3 more observed than expected and 4 more respectively), whereas for the high *Strategic Approach* preference there were 1 more than expected in the low grades group.

A closer look at the *MEQ* points and *BMDT* percentages in Table 54 and Table 55 (representing here students' overall mathematical skills) using independent-samples t-test showed that students with a high *Deep* Approach score had a considerably lower *MEQ* mean whereas for high *Surface* and *Strategic* Approaches the *MEQ* mean is only slightly lower. For the *BMDT* percentages for students with high *Deep* Approach and high *Surface* Approach the mean is higher but slightly lower for high *Strategic* Approach students. The results are only statistically significant for high *Deep* Approach for *MEQ* points which means that students with lower *MEQ's* had a high *Deep* Approach.

	Not high approach			High approach			Variance Assumed	Tests Statistics					
AtS	**N1**	**Mean**	**Std. Dev.**	**N2**	**Mean**	**Std. Dev.**		**t**	**Df**	**sig (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Cohen's d**
Deep	15	105.07	25.944	107	89.40	32.939	N	2.112	120	0.047	-15.665	7.417	0.491
Surface	84	92.12	32.648	38	89.58	32.477	Y	0.399	120	0.691	-2.540	6.372	0.079
Strategic	31	92.26	30.584	91	91.01	33.260	Y	0.184	120	0.854	-1.247	6.782	0.039

Table 54 – MEQ grade summaries for the Independent-samples t-test for AtS High and Not high scores

	Not high approach			High approach			Variance Assumed	Tests Statistics					
AtS	**N1**	**Mean**	**Std. Dev.**	**N2**	**Mean**	**Std. Dev.**		**t**	**Df**	**sig (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Cohen's d**
Deep	12	80.42	13.820	89	84.52	14.251	Y	-0.939	99	0.350	4.100	4.368	-0.292
Surface	73	83.70	15.048	28	84.89	11.893	Y	-0.377	99	0.707	1.194	3.169	-0.084
Strategic	25	86.00	12.835	76	83.38	14.637	Y	0.799	99	0.426	-2.618	3.279	0.186

Table 55 - BMDT percentage summaries for the Independent-samples t-test for AtS High and Not high scores

5.3.3 The relationship between students AtS and module results for UoS

Quadrants in figures 12, 13 and 14 referred to in this section are based on the following interpretation in Figure 11 where quadrant 1 contains students who had *Above AtS mean* (higher than mean of *AtS* score) and *Above Module mean* (higher than mean of module marks). Quadrant 2 contains students with *Below AtS mean* but *Above Module mean*, quadrant 3 is for those with *Below AtS mean* and *Below Module mean* and quadrant 4 contains students with *Above AtS mean* but *Below Module mean*.

Quadrant 2 (-,+) + Above module mean marks - Below *AtS* mean score	**Quadrant 1 (+,+)** + Above module mean marks + Above *AtS* mean score
Quadrant 3 (-,-) - Below module mean marks - Below *AtS* mean score	**Quadrant 4 (+,-)** - Below module mean marks + Above *AtS* mean score

Figure 11 – Format of AtS scores and module results

Figures 12 and 13 show the scatter graph and numbers for Deep Approach scales. The differences in *MSU* and *Non-MSU* in the *Deep approach* gave a significant result ($p<0.05$) for *Below Deep* mean with $\chi^2=7.903$[11], df=2 and p=0.019 (in grey) and non-significant for *Above Deep* mean with $\chi^2=5.509$[12], df=2 and p=0.064.

[11] 4 cells (66.7%) have expected countless than 5=> inflated chi square. Minimum expected 2.09
[12] 3 cells (50.0%) have expected count less than 5=> inflated chi square. Minimum expected 3.25

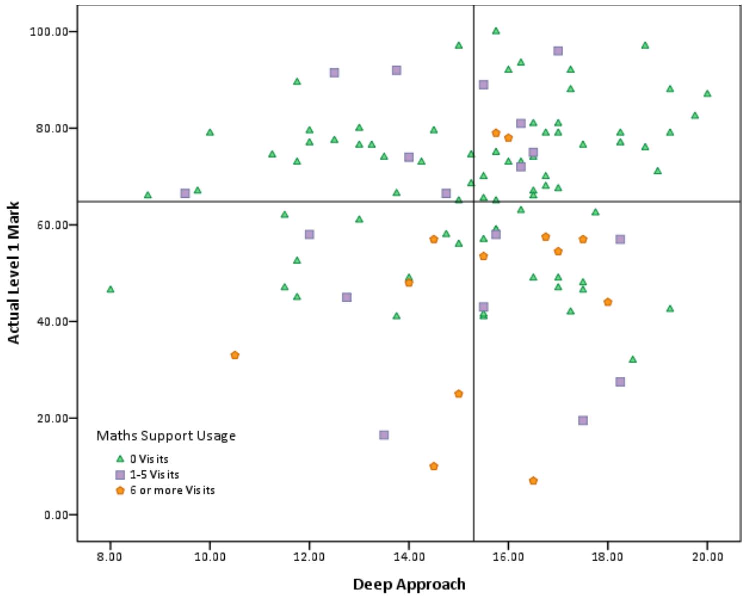


Figure 12 – Scatter-graph of deep AtS scores by Level 1 module results for mathematics support usage

Quadrant 2 (-,+)	Quadrant 1 (+,+)
20 0 Visits	31 0 Visits
5 1-5 Visits	5 1-5 Visits
0 6+ Visits	2 6+ Visits
Quadrant 3 (-,-)	**Quadrant 4 (+,-)**
10 0 Visits	15 0 Visits
3 1-5 Visits	5 1-5 Visits
5 6+ Visits	6 6+ Visits

Figure 13 – Numbers for deep AtS scores and Level 1 module results for MSU

The small number of MSU students in each quadrant makes it difficult to draw any definite conclusions from these data. However, the data may suggest possible relationships between usage and results. The majority of the 6+ visits students fell in the *Below Module mean* marks quadrants 3 and 4; these may have been students who depended on mathematics support to stay on track and keep from failing. It would be necessary to consider the individual students to get a better picture of what is happening. This was not undertaken in this research due to time constraints and has been suggested as a recommendation for future study.

Figure 14 and Figure 15 show the scatter graph and numbers for Surface Approach scales.

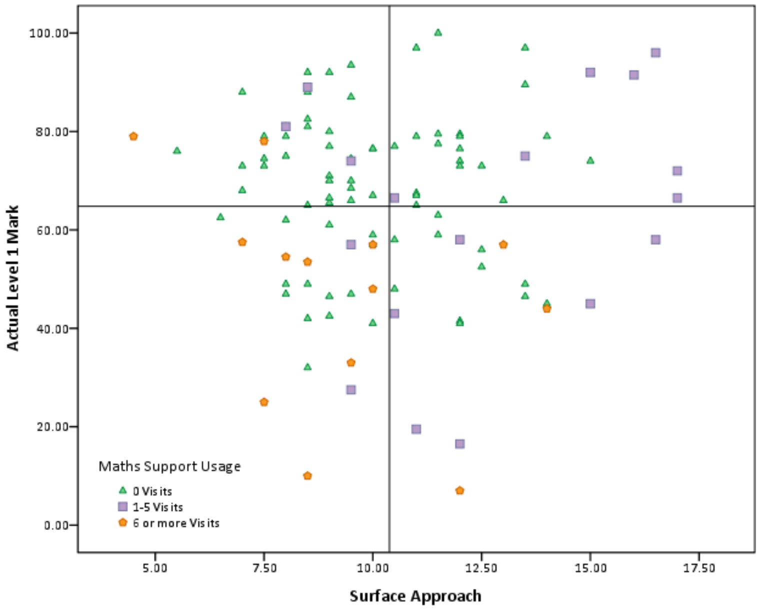


Figure 14 – Scatter-graph of surface AtS scores by Level 1 module results for mathematics support usage

Quadrant 2 (-,+)		Quadrant 1 (+,+)	
31	0 Visits	20	0 Visits
3	1-5 Visits	7	1-5 Visits
2	6+ Visits	0	6+ Visits
Quadrant 3 (-,-)		**Quadrant 4 (+,-)**	
14	0 Visits	11	0 Visits
2	1-5 Visits	6	1-5 Visits
8	6+ Visits	3	6+ Visits

Figure 15 – Numbers for surface AtS scores and module results for mathematics support usage

There is no significance for *Above Surface* approach with χ^2=4.753[13], df=2 and p=0.093 and significance (p<0.05) for the *Below Surface* approach χ^2=8.148[14], df=2 and p=0.017.

[13] 2 cells (33.3%) have expected count less than 5. Minimum expected 1.28
[14] 3 cells (50.0%) have expected count less than 5. Minimum expected 2.00

Here again there were more 6+ visits students in the quadrants 3 and 4 *Above Surface mean/Below Module mean* and *Below Surface mean/Below Module mean*. With the small numbers of students a deeper review is necessary to extract useful information.

Figure 16 and Figure 17 show the scatter graph and numbers for Strategic Approach scales.

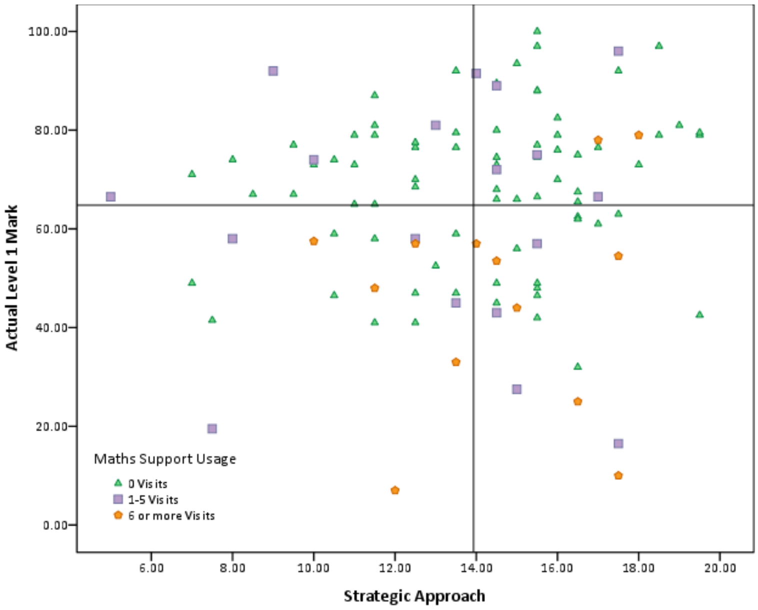


Figure 16 – Scatter-graph of strategic AtS scores by Level 1 module results for mathematics support usage

Quadrant 2 (-,+)	Quadrant 1 (+,+)
21 0 Visits	30 0 Visits
4 1-5 Visits	6 1-5 Visits
0 6+ Visits	2 6+ Visits
Quadrant 3 (-,-)	**Quadrant 4 (+,-)**
11 0 Visits	14 0 Visits
4 1-5 Visits	4 1-5 Visits
5 6+ Visits	6 6+ Visits

Figure 17 – Numbers for strategic AtS scores and module results for mathematics support usage

The plot for the *Strategic* approach is very similar to the *Deep* approach. The chi square test of independence yielded significant results with χ^2=7.664[15], df=2 and p=0.22 for *Below Strategic mean* and χ^2=5.329[16], df=2 and p<0.05 for the *Above* mean.

5.3.4 Approaches to studying versus value added scores for UoS

As per the classic pre and post-test the same test would be presented to the participants but presenting the same mathematics test to the students at the end of the year was not practical. Therefore as noted in section 3.5.1 measures for mathematical skills at Entry (*BMDT*) and Exit (Module Marks) have been used for pre and post-test comparison. Only students who carried out both tests have been included. However as these tests are different, paired t-test was not possible therefore the Independent samples t-test has been used.

Students' strong preference for *Deep*, *Surface* or *Strategic* approaches was used to consider their mathematical skills at the start of their studies and their performance at the end of one year. Tables 56 and 57 provide a breakdown of *BMDT* and Module results for high *AtS* scorers, categorised by mathematics support usage.

The results are statistically significant for both tests for the high Deep and Strategic approach with high effect sizes. The results for the high Surface approach were not significant for either tests.

For all of the approaches the *BMDT* percentage was lower for *MSU* students though for the surface approach students the means are similar. The Module marks for the 3 groups show low means for Deep and Strategic approaches *MSU* students and worryingly, a substantial drop in the mean for the Surface *MSU* students. Larger sample sizes are necessary to draw significant and definite conclusions as to whether that the surface approach may be necessary in the early stages of learning

[15] 4 cells (66.7%) have expected count less than 5. Minimum expected count 2.22.
[16] 3 cells (50.0%) have expected count less than 5. Minimum expected count 3.10

mathematics (Marton, Dall'alba *et al. 1*996). This is further explored in section 5.4 and appendix 20 by factoring out *MSU* to develop a regression model using *BMDT* percentages and *AtS* scores, the results were not significant and at times meaningless and have therefore not been included here but in the appendix for information.

AtS	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		T	Df	sig (2-tailed)	Mean Difference	Std. Error Difference	
High Deep	64	88.48	8.306	14	68.93	20.849	N	3.450	13.915	0.004	19.556	5.668	1.133
High Surface	18	86.28	9.074	4	81.75	11.955	Y	0.857	20	0.402	4.528	5.285	0.262
High Strategic	55	87.58	8.522	13	68.54	21.022	N	3.205	12.946	0.007	19.043	5.943	1.088

Table 56 – BMDT percentage summaries for the Independent-samples t-test for AtS high scores for Non-MSU and MSU

AtS	Non-MSU			MSU			Variance Assumed	Tests Statistics					Cohen's d
	N1	Mean	Std. Dev.	N2	Mean	Std. Dev.		T	Df	sig (2-tailed)	Mean Difference	Std. Error Difference	
High Deep	64	68.48	15.543	14	50.89	28.996	N	2.201	14.674	0.044	17.584	7.989	2.377
High Surface	18	66.22	17.127	4	56.75	33.283	N	0.553	3.361	0.615	9.472	17.124	0.899
High Strategic	55	68.32	16.190	13	50.15	28.466	N	2.218	13.887	0.044	18.164	8.191	1.669

Table 57 – Level 1 module marks summaries for the Independent-samples t-test for AtS high scores for Non-MSU and MSU

AtS	Differences in means		Gap reduced by MSU students	Statistical Sig. of BMDT and Module t-test
	BMDT	Modules	VAS	
High Deep	19.45	18.58	0.870	Sig
High Surface	4.53	9.47	-4.940	Not sig
High Strategic	18.90	19.19	-0.290	Sig

Table 58 - UoS Mathematical skills – value added by mathematics support for level 1 module results

A paired-samples t-test was conducted to evaluate the impact of a semester's worth of teaching and mathematics support (for a few students) on the students' *AtS* scores (Tables 59 and 60). There were only 25 post intervention questionnaires returned and only 4 of these students had made use of mathematics support; therefore this part of the analysis is performed in order to identify improvements that could be made to future studies.

The means of the pre and post scores have been used to compare changes in *AtS* because the *AtS* scales and subscales are made up of sums of scores for the items and not 1-5 Likert scales of the individual questions making up the items. The scores for the *AtS* subscales are made up of the sum of the scores of the 4 different questions (items) for each subscale and the scales made up of the sum of the subscales. These have provided a continuous variable for the scales and subscales, hence comparison of means was deemed suitable.

There was a statistically significant (Table 59) drop in score for *Deep - Use of evidence*, and a significant drop in *Strategic Time-management* subscale and a nearly significant increase in *Surface Unrelated Memorising* subscale. In all these cases the effect size is moderate and small with a mean difference of 6.6%, 6% and 8.6% respectively with respect to a possible total score of 20. The results would imply that after a semester at university the students have altered their *AtS* (possibly under the assumption that this would improve performance on their programme of study) and in this study the surface approach score have increased whilst the deep and strategic had decreased. Repeated studies would need to be carried out over a number of years to see if these results are consistent and if they give strength to the need for procedural approach to studying in mathematics.

AtS Scales	Pre Intervention Mean	Std. Dev	Post Intervention Mean	Std. Dev	Mean Diff	T	Sig	Cohen's *d*
Deep	16.09	2.424	15.72	2.092	-0.37	1.015	0.32	0.2
Surface	10.10	2.354	11.04	2.922	0.94	-1.441	0.16	-0.4
Strategic	14.60	2.854	13.60	3.775	-1.00	1.870	0.07	0.3
AtS Subscales								
DP_IR	15.96	2.700	15.28	2.880	-0.68	1.453	0.16	0.2
DP_UE	16.20	2.930	14.88	3.113	-1.32	2.267	0.03	0.4
DP_SM	15.52	2.830	15.60	3.109	0.08	-0.147	0.88	-0.03
DP_PRP	16.68	2.704	16.56	1.758	-0.12	0.296	0.77	0.1
SR_LP	7.84	3.400	8.16	4.079	0.32	-0.383	0.71	-0.1
SR_UM	10.28	2.700	12.00	3.215	1.72	-2.015	0.05	-0.6
SR_MP	16.84	2.392	16.76	2.1656	-0.08	0.149	0.88	0.04
ST_OS	14.36	3.026	13.60	4.163	-0.76	1.053	0.30	0.2
ST_TM	14.84	3.145	13.64	3.915	-1.20	2.058	0.05	0.3

Table 59 – Changes in AtS mean scores for first year students before and after intervention.

Considering the means for only *MSU* students (Table 60), the only significant result was for the Surface Approach scale. The students' mean after intervention had risen by 3 points, which is 15% of total points available. Anecdotally there is evidence based on support tutors' comments that *MSU* students want to learn to get through the assessments and therefore often work towards learning and memorising processes. However due to the small number of cases and the deficiency in the use of means in this part of the research the result is provided only for information and cannot be confirmed to be reliable.

AtS Scales	Pre Intervention Mean	Std. Dev	Post Intervention Mean	Std. Dev	Mean Diff	T	Sig	Cohen's *d*
Deep	15.94	2.105	16.00	2.944	-0.063	-0.094	0.931	-0.03
Surface	9.25	2.021	12.25	2.630	-3.000	-3.565	0.038	-1.3
Strategic	16.63	1.181	15.75	3.304	0.875	0.701	0.534	0.4
DP_IR	13.25	2.986	14.00	4.899	-0.750	-0.545	0.624	-0.2
DP_UE	16.75	2.630	15.00	3.830	1.750	1.849	0.162	0.5
DP_SM	16.00	2.160	18.00	2.309	-2.000	-2.828	0.066	-0.9
DP_PRP	17.75	1.500	16.75	2.217	1.000	2.449	0.092	0.5
SR_LP	4.75	0.957	8.00	5.657	-3.250	-1.302	0.284	-0.8
SR_UM	12.00	3.464	13.75	3.594	-1.750	-0.592	0.595	-0.5
SR_MP	17.75	1.893	17.25	0.957	0.500	0.775	0.495	0.3
ST_OS	16.00	2.708	14.00	5.164	2.000	1.022	0.382	0.5
ST_TM	17.25	0.957	16.25	2.872	1.000	0.679	0.546	0.5

Table 60 – Changes in AtS mean scores for first year MSU students before and after intervention.

The intervention does not represent mathematics support alone; it also acknowledges the effects of study and learning experiences through other sources on the courses.

However focusing on the mean responses does not adequately represent the changes of *AtS* of individual students and does not capture rise and drop of equal amounts which are lost when using means. The scattergraph of the *AtS* scores before and after the first semester show overall the scores have not changed to a great degree (Figure 18). Note the 4 *MSU* students have been identified as A, B, C and D in the Figures 18 and 19.

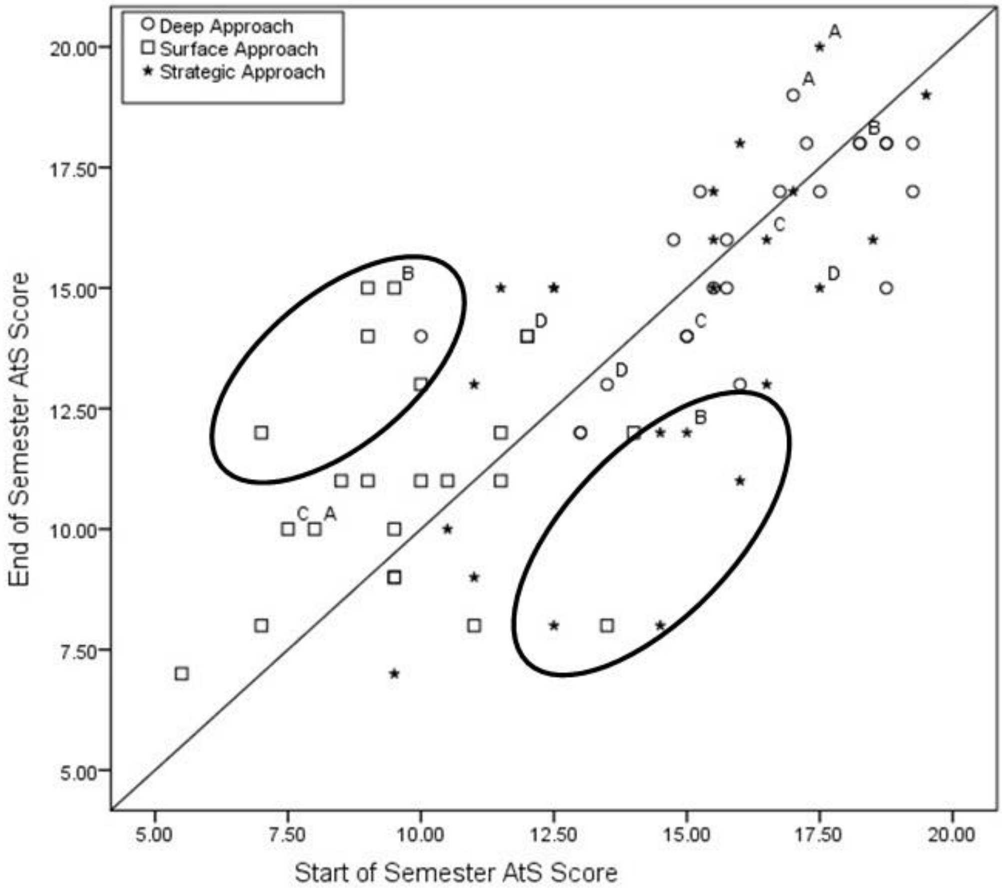


Figure 18 – Numbers for strategic AtS scores and module results for mathematics support usage

There were a group of students whose surface approach score rose after first semester one of the five in this group had made use of mathematics support, which highlights the deficiency of the use of mean to measure changes in the *AtS* scores. In the comparison of the mean differences in the *AtS*; *MSU* students showed an increase of 3 points in the surface approach whereas in reality this was due to a single student as can be seen in Figure 18.

The nature of the *AtS* scales are complex and as a closer examination of the few MSU students shows. One student (B) had increased his score on the surface approach with a similar drop in the strategic but this is not consistent with another student (A) who has very high deep and strategic scores also increases scores post-intervention on all three measures. Students can score high or low on all scales including Deep and Surface which are noted as at the opposite ends. In practical terms there is no reason a student may not select a preference to reflecting on his reading material and to choose to memorise information, approaches belonging to the Deep and Surface Scales respectively. There is an inter-relationship between these scales that cannot be easily defined.

Figure 19 shows the mathematics module marks for the differences in *AtS* scores, Student B who had the increased surface approach score did not pass the module at first sitting, in fact only Student A from the *MSU* group passed the module and his/her *AtS* scores had increased for all three of the approaches by 2 to 2.5. Both Students B and D who displayed an increase in the surface approach and a drop in the strategic approach have failed the module. More cases are needed to determine whether there is a relationship between the changes in *AtS* scores and performance, an extension of this study is recommended.

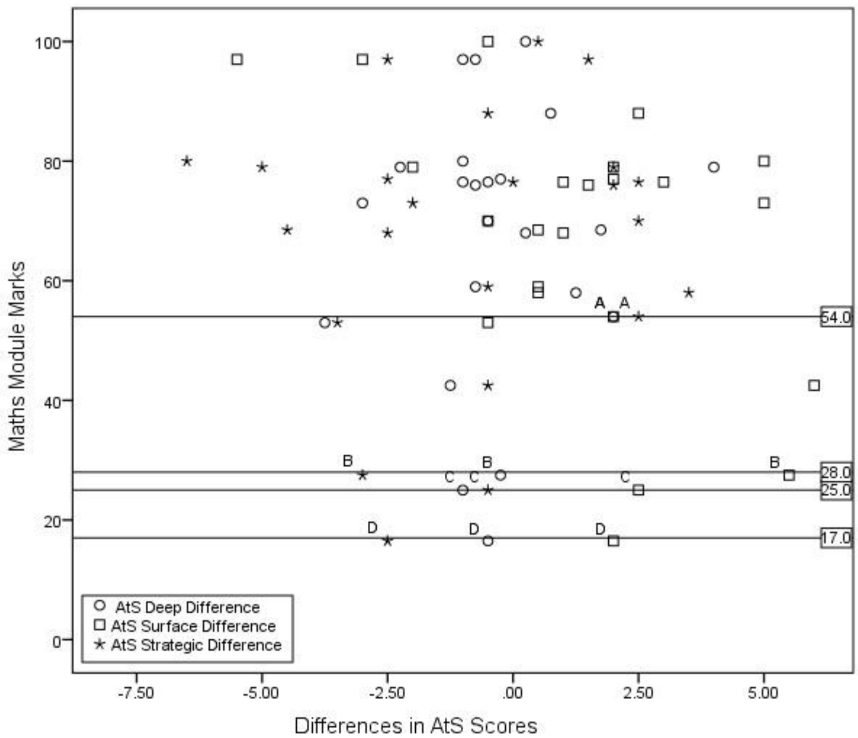


Figure 19 – Numbers for strategic AtS scores and module results for mathematics support usage

5.4 Regression analysis of factors affecting performance on UoS Modules

Simple multiple linear regression analysis was carried out on the UoS dataset for mathematics modules (with prefix MAS) delivered by the department of mathematics. This excludes ACS123 which is delivered by department of engineering lecturers and COM1002 which has a different less mathematical syllabus. By using only MAS modules the analysis is comparing only similar mathematical contents. Additionally there were only 3 students within the *MSU* group for COM1002 making the analysis weak and for ACS123 it was found that the *BMDT* was not a significant contributor to determining module results. ACS123 is the only module that is not taught by the mathematics department and has been developed for more synchronicity with the engineering elements of the programme. Therefore in order to reduce the effects of this different approach on analysis of *MSU* effectiveness, ACS123 and COM1002 results were not included in the regression analysis.

The regression models used the dependent variable Level 1 module marks, and explored the influencing factors *Age*, *MSU* visits, *MEQ*, *BMDT, Attitudes 1-3* and *AtS* scales and sub-scales. Only the statistically significant factors, namely *BMDT* and *MEQ* scores, are detailed in full.

The regression analysis measures the effectiveness of *MSU* on students' mathematical ability. Regression models for *Non-MSU* students' performance was developed which was then used to predict the results for *MSU* students and compared to their actual results.

The main purpose of this is section is to explore a possible method for reducing the bias inadvertently introduced by containing almost all of the *MSU* students and most of the *Non-MSU* students, thus it is neither the whole population nor a truly random sample. Hence by producing a regression model based on the control group (*Non-MSU*) and applying it to the *MSU* students to see if their performance matches the *Non-MSU* students'. The assumption being that both groups apart from mathematics support intervention will have been exposed to the same sources of learning and teaching. However this assumption has to be treated with caution and with the acknowledgment that the *MSU* students may differ from the *Non-MSU* student from the onset possibly having better motivation and/or work ethic. They have shown this already by putting in the extra effort to engage with mathematics support. There is no way of knowing what other resources they would have made use of if mathematics support had not been available. So the findings of the regression analysis does not attribute improvement to mathematics support as there may be other factors influencing the change as well, but mathematics support would be one of them.

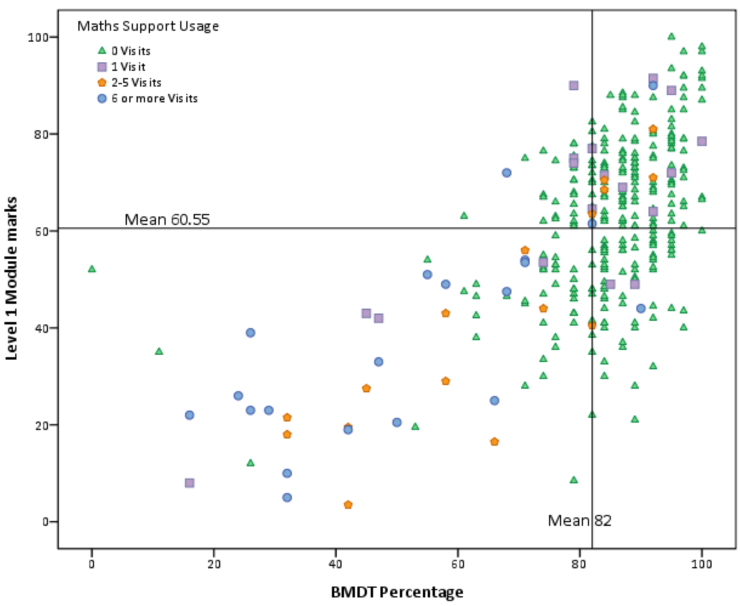


Chart 28 – Linear relationship between BMDT and module results

There is a linear relationship between the dependent variable and the covariate *BMDT* percentages (see Chart 28). The R^2 values (of 0.694 and 0.196) indicate the strength of the correlations between the variables for *MSU* and *Non-MSU* students. In this case for *MSU* students 69.4% of the variance in module marks can be explained by the *BMDT* percentages and only 19.6% for *Non-MSU* students.

The regression model was applied to 278 *Non-MSU* students whose module results and *BMDT* results were available. The initial regression model, used to examine the influence of *BMDT* and *MEQ,* considered the mathematical ability of students at the start of the programme. This was followed by two other models; one introducing *AtS* scales and the other *AtS* subscales.

The results of the correlation between BMDT and MEQ, indicating students' mathematical ability at the start of the programme, together with module marks are summarised below. For overall level 1 module marks the correlation results (see tables 79, 80, 81 and 82 in Appendix 18) were significant for *BMDT* $p<0.005$ and *MEQ* $p<0.05$ for the *Non-MSU* students in the analysis with a reasonable correlation of 0.395 between *BMDT* and module marks and 0.219 between *MEQ* and module marks. There is also an inter-relational correlation of 0.286 between *MEQ* and *BMDT.* The ANOVA (Table 76) gives significant results with F=27.782 df=2 and $p<0.0001$. The multicollinearity of the independent variables is acceptable with the Tolerance and VIF values of 0.918 and 1.089 (Table 78) which are within the required thresholds (Pallant 2005).

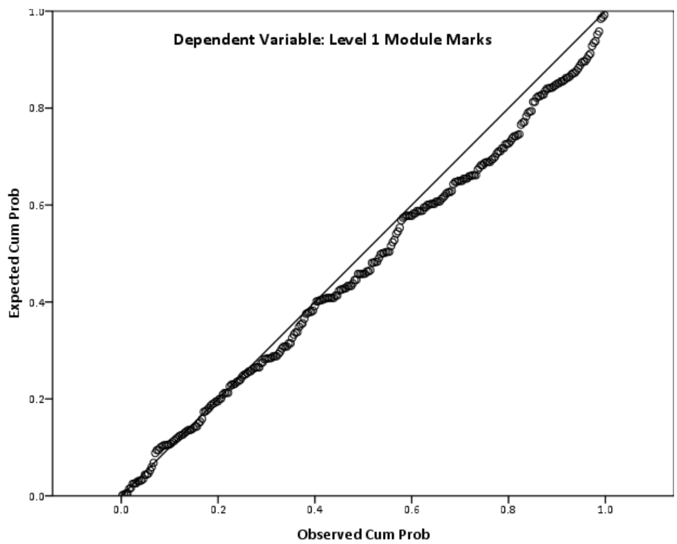


Figure 20 - Normal P-P plot of regression Standardised residual

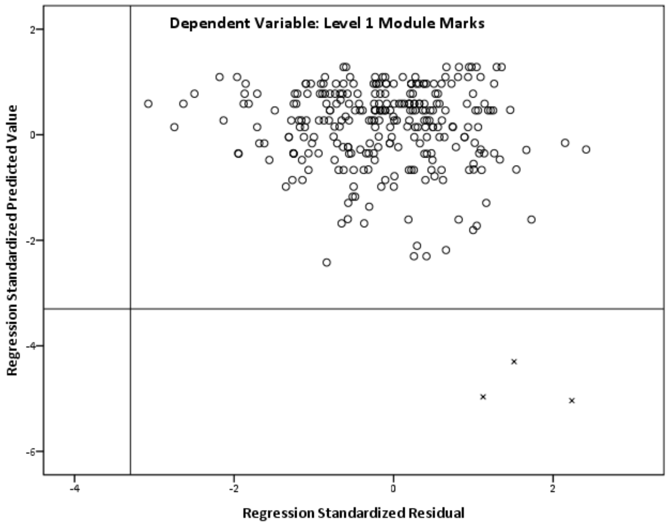


Figure 21 – Scattergraph of regression standardised value

Module marks are normally distributed and the Normal Probability plot and the Residuals Scattergraph plot for the regression suggest no major deviations from normality, the former forming a reasonable diagonal line and the latter presenting a cluster around 0. The points outside +/-3.3 are outliers (marked as crosses). The critical value for the regression with 1 independent variable is 10.83 (Tabachnik and Fidell 1996) and, on close examination of the Mahalanobis distances against the critical values, we find four outliers which are not expected to influence the analysis and hence are not adjusted nor removed. The means and standard deviation for module marks and *BMDT* percentages and *MEQ* grades are 63.49[17] (SD-15.48), 85.73[18] (SD-10.62) and 5.58[19] (SD-0.73). The Adjusted R^2 in this model is 0.168 which is close to R^2 of 0.162 (very similar) hence the prediction model is good, with 16.8% of the variance in the module marks being explained by mathematical ability (based on the *BMDT* and *MEQ* scores) at the start of studies. The resulting regression model for this analysis is:

$$Y_{Non\_MSU\_L1} = 4.547 + 0.528(BMDT) + 2.458(MEQ)$$

Equation 5 – UoS regression model for predicting module results with *BMDT* and *MEQ*

[17] Out of 100 marks with the pass mark of 40
[18] Out of a hundred, less than 70 considered 'at risk'
[19] Out of 6

Using this model on *MSU* students' marks we get a module mean of actual marks and predicted marks (Table 61). The actual marks were greater for each of the *MSU* categories with *Medium* to *Large* effect size (Cohen 1988); the best outcome was for students making 2-5 visits for support.

MSU Category	Mark	Cases	Mean	Std. Dev.	Std. Error	Mean Plus Std. Error	Mean Minus Std. Error	Cohen's *d*
1 Visit	Actual	34	63.92	20.445				
	Predicted	34	43.98	11.08	1.9	45.88	42.08	1.082493
2-5 Visits	Actual	43	43.28	23.35				
	Predicted	43	38.15	12.18	1.858	40.008	36.292	1.009919
6 and more	Actual	49	40.77	22.05				
	Predicted	49	37.91	9.8	1.4	39.31	36.51	0.671923

Table 61 – Actual and predicted marks for mathematics support usage categories and effect size for mathematics ability as predictors

The results in Table 61 show better than predicted scores for *MSU* students. This is especially important for the students who used mathematics support 6 or more times; they had a positive mean difference of 12.7 marks and if the plus/minus standard error was applied then these students would have borderline marks (highlighted in grey) without mathematics support. Thus 49 students predicted to barely pass had passed and mathematics support was one of the factors influencing this result. The effect size for this group is *Medium*. The actual results for 1 and 2-5 visits students was also better by 18.28 and 20.57 marks (*Large* effect size).

Comparing *Non-MSU* and *MSU* students by their *AtS* scores was used in order to identify trends by comparing like *AtS* scores for the *MSU* groups. Therefore *AtS* scales and subscales scores were used in the regression analysis but the results were not significant due to the need to relax the p value to 0.5 and in fact the predicted results gave wrong results i.e. negative module mark in one case for 2-5 MSU visits student group. The newer models with *AtS scores* have been included in

Appendix 20 for information only with recommendations for further similar work with a larger sample size for reliable results.

No major gender differences were identified except females were predicted to score higher than they actually did. For level 2 modules the performance (Chart 29) was the same for both males and females.

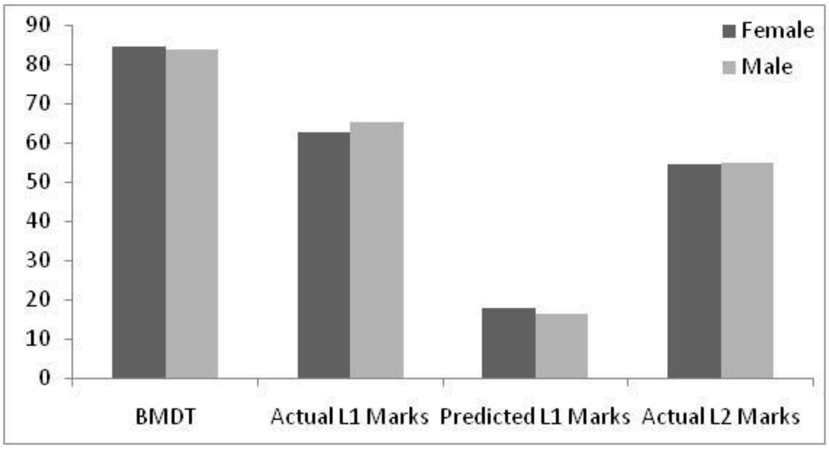


Chart 29 - Gender by mathematics ability at start, results and predicted results

AtS profiling review of the differences in gender showed the males had higher Deep and Strategic Approaches (Chart 30). In a science based discipline this may be an area for further review with respect to females' self-perception. A similar breakdown by *AtS* Subscales gave similar results (not shown here).

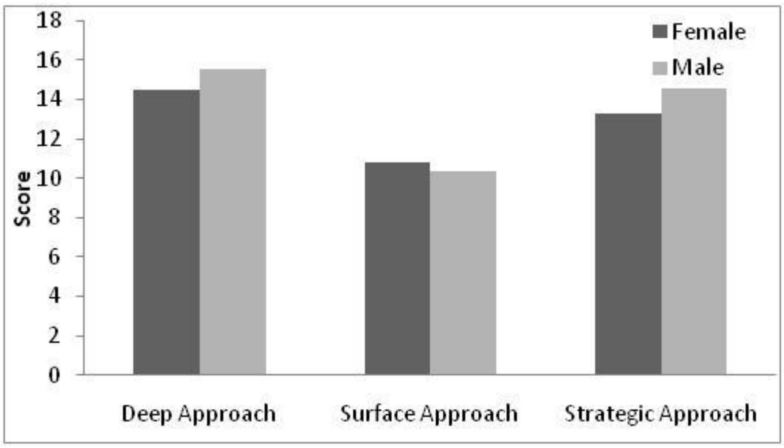


Chart 30 - Gender by AtS scales

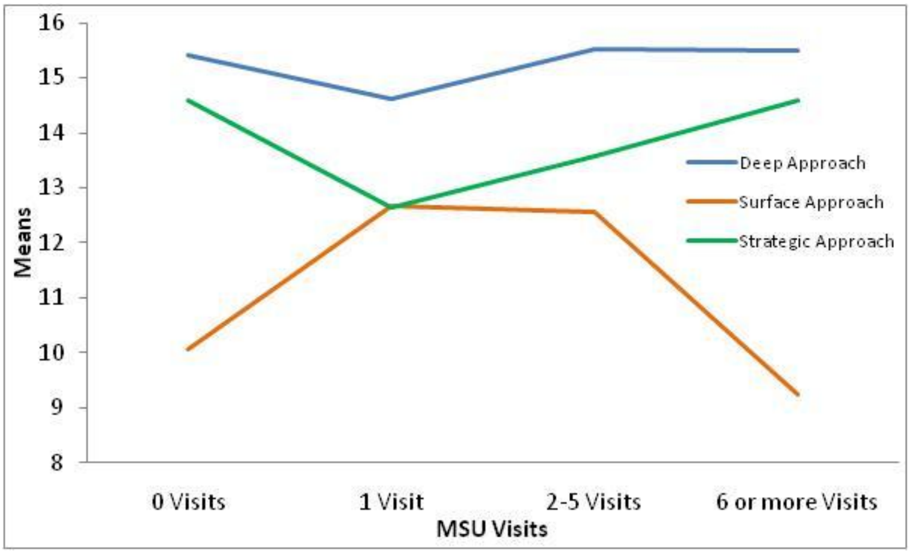


Chart 31 - MSU groups for AtS scales

Students with high Surface Approaches did not continue long term usage (more than 5 visits) of mathematics support. But the Strategic Approach students did continue use of support.

The interpretation of this is that while a Deep Approach led to level usage, Surface Approach students did not continue engagement and Strategic Approach students increased engagement. A closer look at these through a review of the sub-scales shows (Chart 32) that it is the Surface Lack of purpose that is 'dragging down' the Surface Approach results.

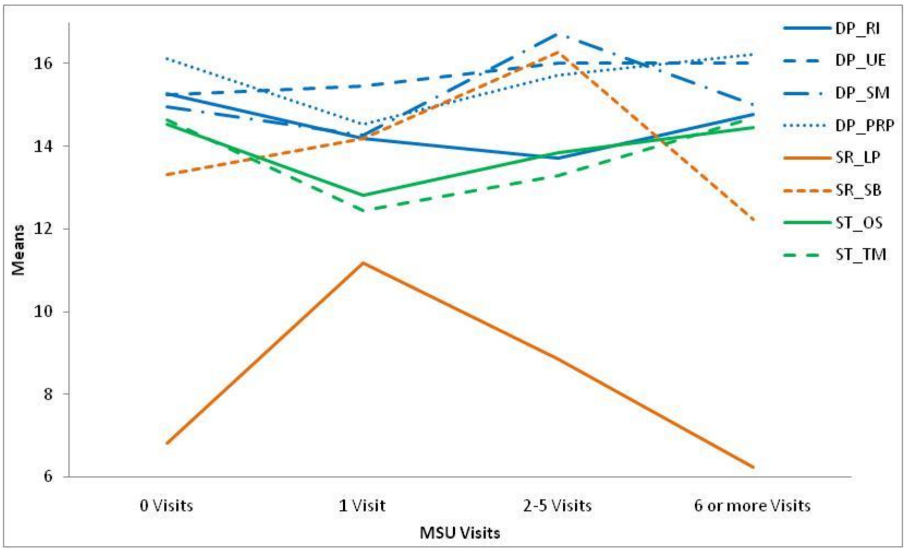


Chart 32 – MSU groups for AtS subscales

The mathematics support usage patterns for the deep subscales (Relating Ideas, Seeking Meaning, Use of Evidence and Procedural Relating Processes) are similar to each other. The similarity is even more distinct within the strategic subscales (Organisation Skills and Time Management). However students with low surface subscales scores did not make prolonged use of mathematics support.

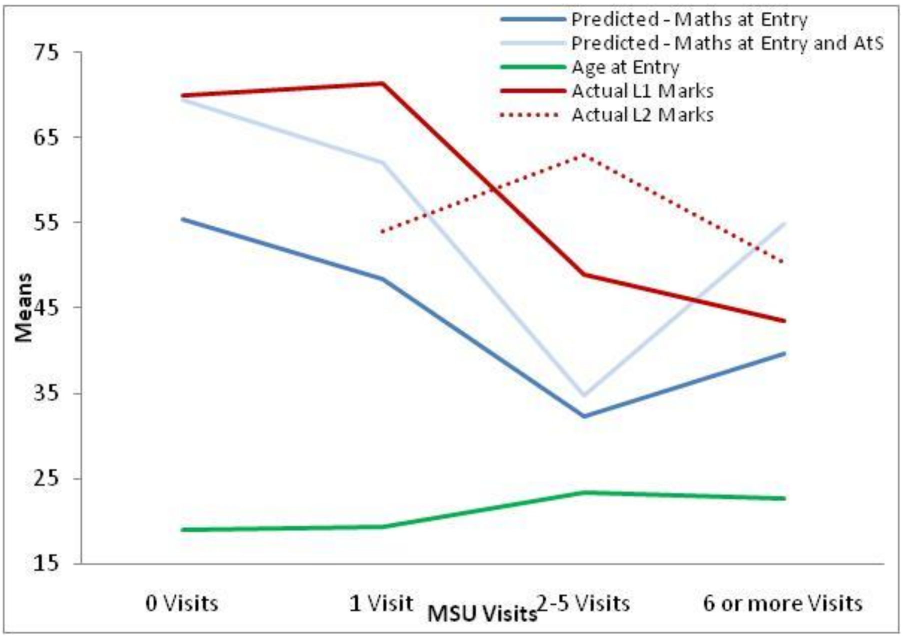


Chart 33 - MSU groups for profile and outcome

The older students made more use of mathematics support, and overall those who made use of mathematics support got better scores than their predicted scores.

For all three high approaches' means (Chart 34, Chart 35 and Chart 36) show that *BMDT* percentages are a good predictor of performance regardless of preferred studying approach. Deep and Strategic high approaches follow similar trends in usage except that the Deep high approach students continue to improve with mathematics support at level 2 (Chart 34 and Chart 36 – red dotted line). However, this has occurred only in this set of data. The analysis would need to be repeated with other data to see if the results can be reproduced.

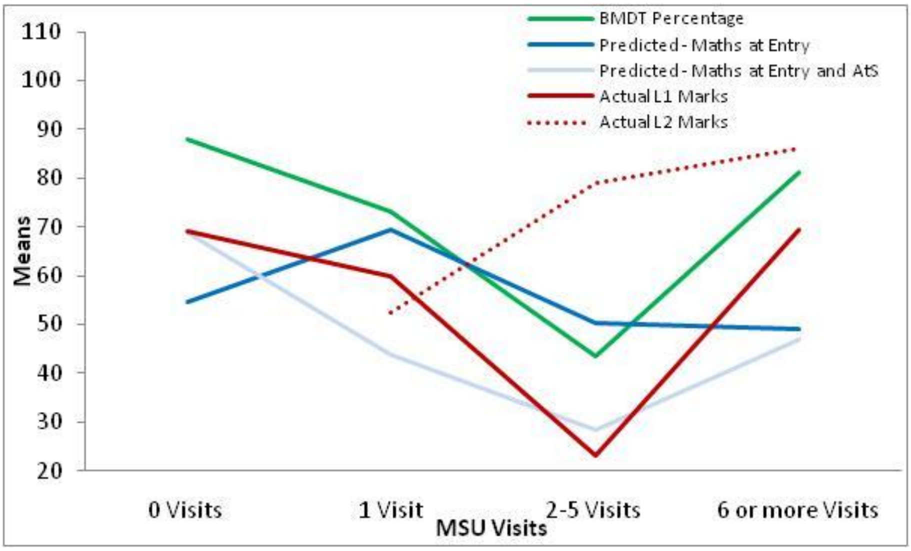


Chart 34 - Entry and outcome results for high Deep Mean Approach students

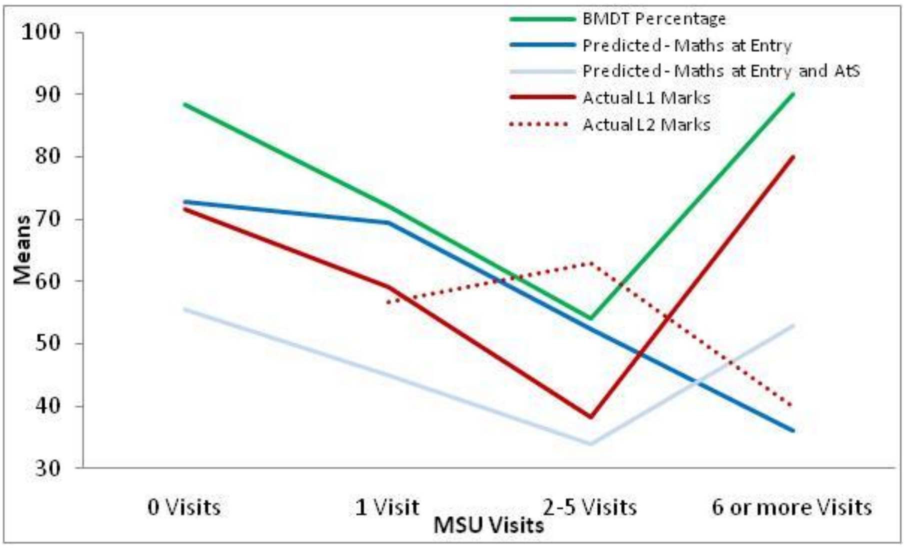


Chart 35 - Entry and outcome results for high Surface Mean Approach students

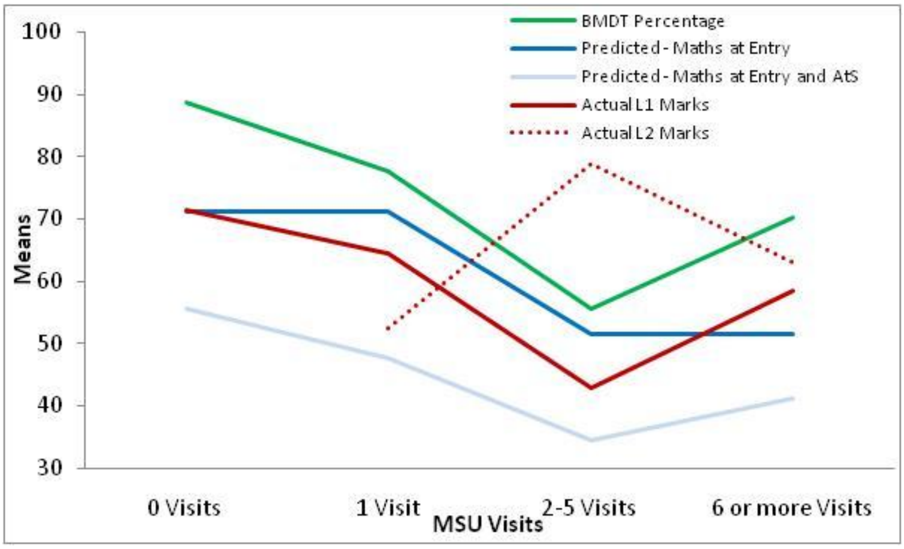


Chart 36 - Entry and outcome results for high Strategic Mean Approach students

6 Results and conclusions

In this chapter the results are discussed and conclusions drawn for the formation of a model for measuring the effectiveness of mathematics support and for better prediction of students' performance in mathematics based on the regression analysis. The purpose of predicting performance is to optimise mathematics support resourcing.

6.1 Profile of mathematics support users

6.1.1 Profile by mathematics skills at entry

Statistically significant numbers of students who used mathematics support had lower mathematics entry qualifications at both universities; at RGU 39 at UoS 42 students compared to 78 and 170 with higher mathematics entry qualifications for RGU and UoS respectively. That is half for RGU and nearly a quarter for UoS. The majority of these students had a *Vocational or Foundation* entry qualification which further exasperates their preparedness, first because the above average age of this group, implies a break from continuous education and secondly because the mismatch, between the mathematics required for their main programmes of study and entry mathematics, is greater (Hobson and Rossiter 2010). Recently at UoS along with the available mathematics support, specific workshops have been introduced to help students revise and learn mathematical topics known to be missing or weak within this group. This statistical significance is present whether considering *MEQ Types* (traditional A-Levels or Highers or non-traditional Vocational or foundation courses) or *MEQ Grades.*

Additionally, the Independent-samples t-tests for *BMDT,* comparing *MSU* and *Non-MSU* students, showed that the *MSU* students had significantly lower *BMDT* percentages for all the student cohorts. For RGU's three tests the mean differences (lower for *MSU* students) were 20.6%, 10.9% and 2.2% and for UoS's modules, the mean differences were 21.4% (only one not significant), 21.5%, 20.1%, 2.3% and 24.5% (see Table 22). The effect sizes of these differences for RGU were *small* for two tests and *large* for one; for UoS three were *large* with one *small*.

The weaker mathematical ability of *MSU* students at entry, evidenced by the *MEQ* and *BMDT* scores here, is also confirmed through the studies by Croft and Grove (2006), Patel and Little (2006) and Mac an Bhaird, Morgan *et al.* (2009).

A closer look at the mathematics support usage numbers for better prepared entrants, which are higher in numbers, shows that at RGU the largest *MSU* group was the *6 or more visits* and at UoS the *2-5 visits*. Within the less prepared entrants the largest category at RGU was *2-5 visits* and at UoS it was fairly even for all the categories.

Overall, the results show that there is proportionally higher usage by students with lower mathematical skills at entry, possibly motivated by the need to succeed, but there is also usage by the stronger students who made more repeated visits, indicating a studying approach aimed at improving performance, also noted by Pell and Croft (2008). As one of the key aims of mathematics support is to improve performance and hence reduce attrition, attracting the weaker students at entry helps meet this need efficiently.

6.1.2 Profile by attitudes towards mathematics

A significant correlation was found between a positive attitude towards mathematics (as described by confidence and enjoyment) and sustained usage of mathematics support. Students whose past experience was only fair had taken advantage of the support available much more. However this rule did not stand true for students finding mathematics *interesting.* There is sufficient doubt about students' interpretation of the question scale, i.e. *find it enjoyable* had a lower (likert) scale median score than *find it interesting,* the distinction between *enjoyable* and *interesting* not being an obvious one though *interesting* was meant to imply a deeper approach, to not be able to draw any final conclusions from this.

A similar review of the UoS dataset was not possible due to there being only 37 results leaving too small a number of cases (4) within the *MSU* groups.

The two-way ANOVA tests on *Attitude-1* at RGU[20] revealed an interactive relationship between participation in mathematics support and self-perceived confidence in mathematical ability ($p<0.05$). These gave significantly better results for repeated *MSU* by those with *exceptional* or *good* confidence.

Prolonged *MSU* helped students in *Attitude-2* who were *indifferent* or *found mathematics interesting* or *enjoyable*. Those who *didn't find mathematics enjoyable* were helped but not with prolonged visits. These results have not shown any statistical significance and there were too few students within the *MSU* groups to be useful for incorporation in further analysis.

6.2 Value added by mathematics support

The analysis of performance on modules (chi-square tests on RGU module grades and independent-samples t-test on UoS module marks) showed that for the engineering mathematics modules (not including the computing mathematics modules CM1003 and COM1002) *MSU* had added value to students' mathematical skills development. This was consistent for the mathematics modules at both universities. However, at both universities the students from the computing mathematics module had not benefited from mathematics support i.e. they had not improved (more than the *Non-MSU*) on their mathematical skills at entry (measured using *BMDT* scores). This outcome leads to questions regarding suitability of the *BMDT* used for the computing courses and whether computing mathematics has different support needs than those currently being addressed.

[20] Only the RGU dataset is considered here due to sample size requirement minimum 150

Independent samples t-tests on first year mathematics modules for *Non-MSU* and *MSU* students showed *Non-MSU* students' mean scores were better than the *MSU* students'. However, considering the weaker mathematical skills of *MSU* students (*BMDT* or *MEQ*) at the start, the improvements made by them were larger than improvements by the *Non-MSU* students.

Out of the seven first year mathematics modules at RGU and UoS, six showed value added to mathematical skills (based on *MEQ* and *BMDT* scores) at entry, the only module not showing value added being the computing mathematics module. The positive differences in grade means ranged from 0.164 to 0.636, the negative differences -0.03 and -0.081 have been excluded because they are very small and the corresponding results for the *BMDT* percentages mean differences for these modules were positive and strong. The *BMDT* percentage value added measure, only calculated for UoS, ranged between 2.727 and 22.807. These differences, especially at the extremes, could mean the difference between passing and failing modules; i.e. without mathematics support the results in terms of result percentages could be a reduced range of 17-37%.

Using the value added measure for UoS modules for *Non-MSU* students (Section 5.2.1) who had failed to get pass marks showed potential benefits (conversion to pass marks) for 83 students out of the 112. This is a substantial number of students over 5 academic years who may have withdrawn as a result of failing these modules. The cost of losing the income due to these students withdrawing provides a strong argument for funding mathematics support.

6.3 Procedural deep and procedural surface AtS

Students' *AtS* scores were based on the ASSIST (Tait, Entwistle *et al*. 1998) instrument for identification of students' deep, surface or strategic approaches to studying. The questionnaire was augmented to introduce 2 new subscales to examine whether a procedural approach is a useful measure in mathematics. The new subscales trialled were *Deep – Procedural relating processes* and *Surface – Memorising processes.*

Reliability and principal components analysis were carried out on the *AtS* scales and subscales. Of the 11 subscales used in the questionnaire 3 failed the reliability test and were not included, *Procedural surface* (written for this research) being one of those excluded.

The three scales found to be reliable were (with their corresponding Cronbach's alpha's); *Deep Approach* 0.880, *Surface Approach* 0.627, *Strategic Approach* 0.794. The eight subscales were *Relating Ideas* 0.736, *Seeking Meaning* 0.703, *Use of Evidence* 0.557, *Relating Processes_PD* 0.659, *Lack of Purpose* 0.696, *Syllabus-Boundness* 0.563, *Organised Studying* 0.567, *Time Management* 0.715. Four of the Cronbach's alpha values were weak (below 0.7) and two were only acceptable if rounded up.

The principal component analysis placed the new subscale *Procedural Deep* within the Deep approach with a strong loading of 0.821. Cluster analysis on the subscales again revealed a strong loading towards the Deep approach but also an acceptable loading of 0.309 towards the Strategic approach. This gives confidence to the case that a procedural approach can be placed within the 3 original approaches. However only Procedural deep achieved reliability. To ensure a balanced view of procedural approaches, the Procedural surface subscales need to be reviewed and refined. The usefulness of *AtS* scores for measuring effectiveness of mathematics support is summarised in the next section.

6.4 AtS and performance by mathematics support users

The *AtS* results are for first year engineering students who returned a total of 105 fully completed questionnaires with a further 17 completed by second and third year students, 25 of the students having additionally completed a shorter version of the questionnaire to further explore changes in approaches after a semester.

The students with high *Deep* and high *Strategic* approaches scores had considerably lower *MEQ* and *BMDT* scores than their peers (statistically significant) compared to the only slightly lower *MEQ* scores for high *Surface* approach students compared to peers. This begs a question about the suitability of the *Deep* approach at the pre-HE entry stage as these students with self-perceived high *Deep* and *Strategic* approaches had not performed well. Of course this one highlight does not mean anything without more research on approaches at pre-HE level to see if there are any issues for Deep and Strategic learners in terms of their learning development. But if this apparent phenomenon can be confirmed it would mean a change in the teaching approach at Pre-HE should be explored.

Considering the performance of high *AtS* scales it was found that for all High *Deep, Surface* and *Strategic* scales MSU students had lower mathematical skills at the start. Comparing, for *Non-MSU* and *MSU* group's the differences in means of *BMDT* and modules marks which give the value added measure for *MSU* students (Table 58) high *AtS's* did not show an improvement for *Deep* and *Strategic* scales and for the high *Surface* approach there was a substantial a drop in performance. However these results are based on only 4 *MSU* students and are therefore not conclusive.

A paired-samples t-test was conducted on the 25 cases where pre and post semester *AtS* scores were available to evaluate the impact of studying for a semester. The results here also indicated a drop in *Deep* and *Strategic* approaches scores and an increase in the *Surface* approach. In terms of the significant subscales' results *Deep – Use of Evidence*, *Strategic – Time Management* dropped and *Surface-Unrelated memorising* increased, but note this subscales failed the reliability test. But even without that it would appear students were choosing a lesser Deep approach. Of the 25 students in the paired t-test only 4 were *MSU* students and they had a statistically significant increase in their *Surface* approach scale to the value of 3 points which is 15% of the total possible. Therefore after a semester of studying at university the students had changed their approaches to a more *Surface* approach, more so the *MSU* students. The implication of this may be that the individualised mathematics support was encouraging the development of a more surface approach to studying. This is not totally unexpected as the need for practice of mathematical skills is emphasised at the mathematics support centre. However the change in the *Surface* scale of 3 points was due to one student only and therefore it is not possible to draw conclusions. A better confirmation of a change in the *Surface* approach may be possible with a similar study on a larger sample with more work on the *Procedural surface* subscale. The new subscale was piloted but was found not to be reliable thus it is recommended to introduce and run a reliability test on a new set of questions for the subscale followed by integration into the *Surface* scale. The *Procedural surface* questions should be suitable for the mathematics discipline which was the reason for introducing *Procedural deep* and *Procedural surface* to the original ASSIST Instrument.

Of course describing students with either/or *approaches* is overly simplistic and as stated before students are more complex than categorising suggests as seen in the *AtS* analysis. Use of the words 'deep', 'surface' and 'strategic' may be creating a tension in desiring the deep approach when there is the need for a surface approach to master skills through memorising and practice. Only after these skills are mastered can the learners switch between them to apply and develop in a variety of situations.

Literature already suggests a consistent relationship between academic success and strategic approaches (Entwistle, Tait *et al*. 2000) that avoid habitual use of surface learning, but as this is not in a mathematics learning environment, the present research adds another perspective. Another dimension for further consideration is continued work on assessment setting for understanding rather than just ability to show correct information which needs the students to take a surface approach to learning (covering large breadth but lacks depth).

There is enough useful information on *AtS* in this research; therefore the scores are used to refine the regression model for predicting performance discussed in the next section.

6.5 Predicting performance using factors

A multiple regression analysis on the RGU dataset led to the regression model for predicting performance of Y_{RGU_L1} = 4.603 + 0.510(*BMDT*). *BMDT* standardised by the mean and standard deviation giving a range of (-52571, -2.2790). Applying the model to the UoS dataset resulted in a predicted level 1 mean grade of 4.6 which was 0.2 less than the actual overall grade for level 1 modules. To improve on this model, UoS results were used along with the students' *AtS* scores.

Multiple regression analysis was used to identify predictors for performance on mathematics modules at UoS. *BMDT* was used to measure students' mathematical skills at the start of the programme and the influences of *AtS* scales and subscales were put into the regression model. Possible sampling bias within the dataset was addressed by forming models based on the control (*Non-MSU*) group, the resulting models being applied to the *MSU* students in order to assess the effect of intervention.

Three regression models were developed; the first one (Y_1) (statistically significant) is based on the mathematical ability at entry (*MEQ* and *BMDT* scores). The second included *AtS* scales (Y_2) but was only significant when the p-value was relaxed to 0.5 and the third, incorporating the *AtS* subscales (Y_3), was not significant therefore the last 2 models are only for information and for future study possibilities.

$\boldsymbol{Y_1}$ = 4.547 + 0.28(*BMDT*) + 2.458(*MEQ*)

$\boldsymbol{Y_2}$ = -19.513 + 1.056(*BMDT*) – 4.028(*MEQ*) – 0.547(*Deep*) + 1.003(*Surface*) + 1.097(*Strategic*)

$\boldsymbol{Y_3}$ = -2.63 + 1.024(*BMDT*) – 4.797(*MEQ*) – 0.035(*DP_RI*)[21] - 0.574(*DP_UE*) – 0.949(*DP_SM*) + 0.798(*DP_PRP*) + 1.092(*SR_LP*) – 0.167(*SR_SB*) – 0.488(*ST_OS*) – 1.380(*ST_TM*)

In **Model 1** the actual marks were higher for each of the *MSU* categories (by number of visits) with *small* to *medium* effect size (Cohen 1988); the best outcome was for students making 2-5 visits for support where there was a better actual mark of 20.57 versus 18.28 for 1 visit students. However the result for the 6 or more visits is important as the predicted marks (using the model) for these 49 students was borderline, though they actually passed with mathematics support intervention.

In **Model 2** the actual marks were higher for 1 visit and 2-5 visit students for 6 or more visit students the actual mark was less than predicted by 1.57. The best results were for the 2-5 visit students who were predicted to fail (only 4 cases) but actually got 23.29 marks more than predicted. These results were not significant and are only provided here for information.

The predicted results in **Model 3** were very poor and not considered reliable even for information due to the small number of cases and large numbers of variables in the model.

The models containing the *AtS* scales and subscales were not significant but indicated better results for *MSU* students. Model 1 does give significantly better results for *MSU* students and does deal with the possible bias of *MSU* students choosing to engage with the support provided as the models are based on the *Non-MSU* (considered the control group) student cohort. This approach for measuring effectiveness needs to be used again to see if the results are consistent and reliable with different student groups. This is recommended for further research.

[21] DP-RI=Deep-Relating Ideas, DP-SM=Deep-Seeking Meaning, DP-UE=Deep-Use of Evidence, DP-PRP=Deep-Procedural Relating processes, SR-LP=Surface-Lack of Purpose, SR-SB=Surface-Syllabus Boundness, ST-OS=Strategic- Organised Studying and ST-TM=Strategic-Time Management

The impact of the analysis in this study on the mathematics problem debate is that mathematics support does attract the group it is intended for, thus the extra-curricular provision outside of the curriculum is proving to be successful. Using support is having a positive effect on performance though prolonged use of support does not show continued improvement in this study.

7 Recommendations and further work

This chapter considers implementation of the models developed in chapter 6 for improved mathematics support and prediction of performance and makes recommendations. It also suggests further work for improving these models to address some of the limitations discussed.

7.1 Measuring effectiveness of mathematics support

Measuring effectiveness in this study has been done in terms of performance; with a review of performance by students with particular *AtS*'s. Hence the study of students' learning and understanding has been limited, but Schoenfeld's (1985) work on teaching problem-solving in mathematics may provide a way forward for further research in more narrowed down understanding and measuring of mathematical understanding. His work was based on the definition of understanding mathematics as the ability to solve problems. Schoenfeld (1985) definition of problem solving in mathematics is given in terms of *resources* (mathematical skills), *flexibility* (appropriate translation of skills) and *efficiency* in applying these. Resources are the fundamental mathematical skills available for students to use flexibly and efficiently (heuristics) to solve problems. These problem solving skills along with mathematical perspective (belief) and engagement with mathematics make up mathematical thinking (Schoenfeld 1985). Schoenfeld has developed a Knowledge, Attitudes and Behaviours (*KAB*) model (Figure 23) for measuring mathematical learning.

The learner's attitudes both reflect and impact the learner's acquisition and comprehension of knowledge. Learners' attitudes impact and evolve and as a result learners' behaviours give us a more complete understanding of the impact of the educational intervention (see Figure 22).

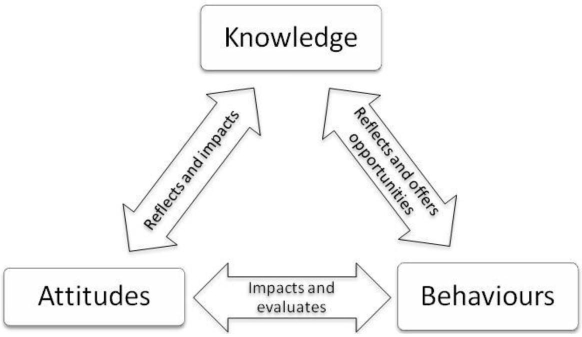


Figure 22 – KAB as a measure of learning development

Measuring the student's engagement in mathematics support in this research has been limited to overall performance which has been used to crudely measure mathematical ability. There has only been a review of changes in students' *AtS* scores which are indicative of changes to a small degree in students' behaviour and thinking. Researching actual understanding and evaluating changes in the learner's knowledge as well as the learner's attitudes and behaviours would give us a more complete understanding of the impact of mathematics support (Cardella 2008). Schoenfeld (1992) has provided a possible map (Figure 23) for researching these three constructs and adapting them to the mathematics support context and this may provide a meaningful measure of effectiveness.

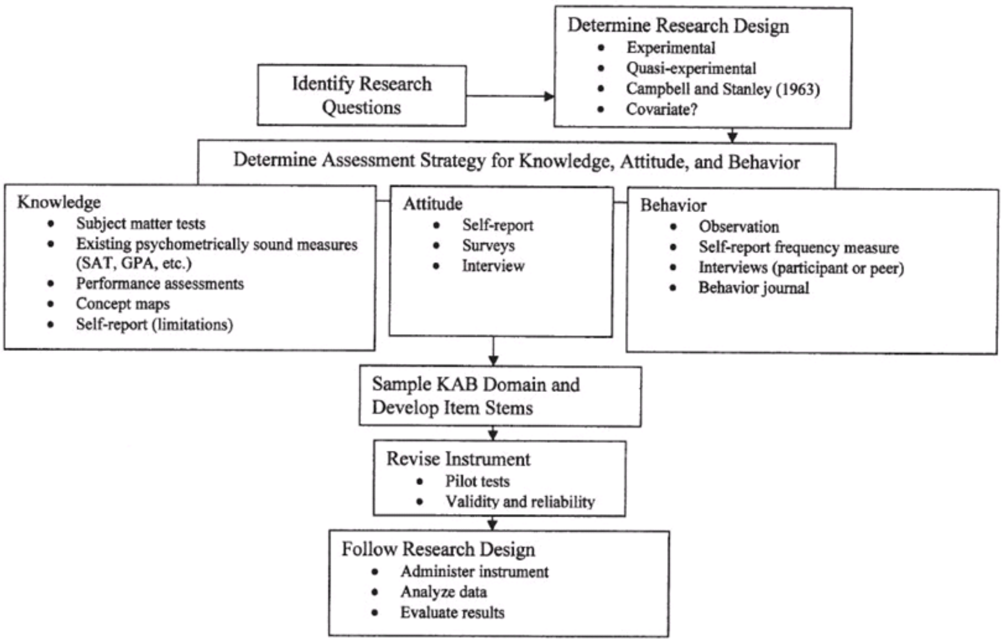


Figure 23 – KAB research design

7.2 Improving AtS and attitudes to mathematics instrument(s) in mathematics support setting

One of the aims of this study was to evaluate the suitability of the *Deep* approach within the mathematics discipline at the early stages of engineering degrees. There is some indication that this approach has not been preferred after a semester of studies whereby there was a decrease in the *Deep* approach and an increase in the *Surface* approach, though this has not been confirmed with statistical significance. The research has already found a new *Procedural Deep* subscale that fits into the *Deep* approach; refining the questions for the *Procedural Surface* could be developed and a new instrument containing the procedural subscales could be used as it offers a finer measurement for approaches to studying in mathematics. Increasing the sample size for the study on students *AtS* and refining the ASSIST+ questionnaire for the *Procedural Deep* and *Surface* subscales may be the actions needed to gain significance and a better match to approaches to studying than that offered by the current breakdown of *Deep*, *Surface* and *Strategic* only.

While this research adds to understanding of patterns of study behaviour in relation to academic achievement, and indicates some general influences of methods of teaching and assessment, it is much less successful at providing full or detailed descriptions of individual student learning. Liston and O'Donoghue (2009) have shown concern about whether the questionnaires are really able to give a true picture of the student's *AtS* or whether we are only managing to capture the student's perception of their *AtS.* The students may not be studying as indicated by their responses but may instead be selecting *how* they would like to study or be perceived as studying. Therefore qualitative methods for a fuller analysis are necessary. The phenomenographic approach (Cohen, Manion *et al.* 2000) is recommended to explore the more subtle factors related to the student's psychological processes such as confidence, self-esteem and changes in approaches to studying due to the influence of mathematics support interventions. Openended questions along with the scales for the *AtS* would help capture more information on students' studying patterns.

The relationship of *AtS* scores to the teaching styles adopted in teaching mathematics has been investigated by Hambleton *et al* (1998) where a comparison was made of the influence and effectiveness of a personalised system of instruction and traditional lecture-tutorial methods for students with different *AtS* scores, but the relationship of mathematics support methods for *AtS* peculiarities of students has not been studied and this would be a worthwhile exercise. Additionally a more detailed study of the individual students and their preferences for AtS and module marks in this research would shed more light is the area.

7.3 Improving effectiveness of mathematics support

Research on engagement with mathematics support was restricted to attendance therefore examination of particular methods in relation to *AtS* is recommended. The different types of support can also be broken down (Table 62) into '*modes of access*': drop-in support offers 'here and now' support with a tutor, whereas the booking of support appointments allows for planned and organised studying. Web-based and resource-based support can be more individually driven or *'self-directed'*. Finally, the '*timing'* of accessing support within students' academic courses: some students will use the support early in their studies to manage to keep up with understanding the main programme of studies. Other students will seek out support as they need it during their programmes and some will attend at the end of their course to revise for up-coming exams. Students' *AtS* scores may influence the preferred mathematics support method.

Timing/ Mode	Start of module	Middle of module	End of module
Immediate	Drop-in for tutor support Workshops Diagnostic testing and follow-up	Drop-in for tutor support Workshops Diagnostic testing and follow-up	Drop-in for tutor support Workshops Exam revision
Planned	Booked Appointment with tutor Workshops Diagnostic testing and follow-up	Booked Appointment with tutor Workshops Diagnostic testing and follow-up	Booked Appointment with tutor Workshops Exam revision

Table 62 – Intervention combinations

7.4 Improving measuring of long term effects of mathematics support

A non-longitudinal arrangement for the RGU data obtained by separating out level 1 and 2 modules reveals that for level 1 the results for *Non-MSU* and *MSU* are similar but for level 2 modules there is an improved pass rate of 12.9%, thus indicating a longer term positive effect of mathematics support. A similar result was found in an earlier study by Patel and Little (2006), where an improvement of 4% for combined levels was observed.

MSU has added value for both institutions; at RGU the mathematics support helped students maintain peer equivalent performance in Year 1 and in Year 2 *MSU* students actually performed better than their peers. Here better results do not mean better grades; rather, they mean greater improvement in mathematical skills. However the same was not true of UoS where the MSU students did well in Year 1 but in Year 2 it was the *Non-MSU* students who made the greater improvement on their mathematical skills. The longer term effect of mathematics support is found to be positive for the RGU dataset but this was not supported in the larger UoS dataset. The reasons for this difference are not clear e.g. whether this is due to the differing cohorts of students at the two institutes is unclear and worth bearing in mind. This may therefore be an area worthy of further research.

The students at RGU and UoS who used mathematics support in year 1 had significantly lower entry qualifications but they improved on their performance more than those who used mathematics support in both years. If this result can be replicated it could help alleviate concerns over developing dependency on support to maintain good performance.

7.5 KAB research design in a mathematics support setting

Using Schoenfeld's KAB model the above recommendations are summarised for further work. The recommendations on refining the analysis in this study have been placed within the three elements Knowledge, Attitudes and Behaviours (illustrated in Figure 24).

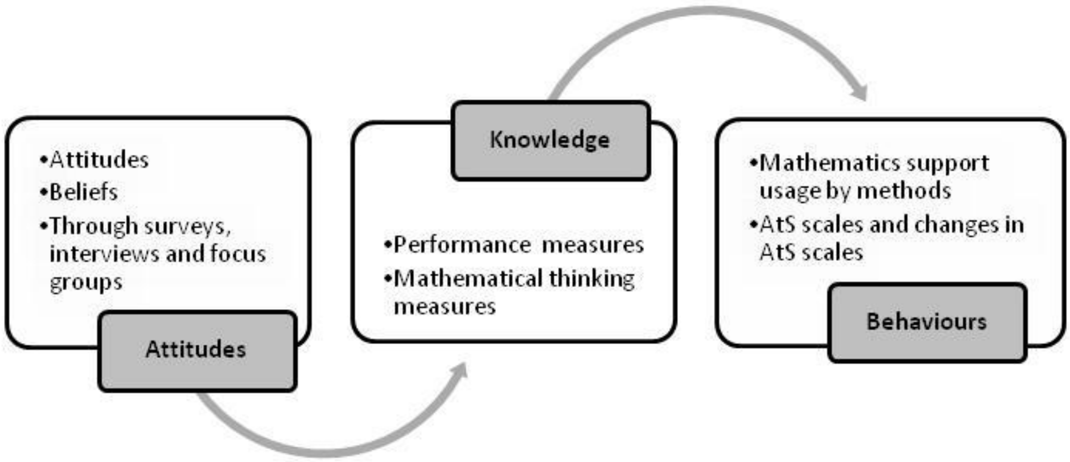


Figure 24 – KAB research design in a mathematics support setting

The recommendation of this research for improving measuring the effectiveness of mathematics support is to use the elements that indicate mathematical thinking; Knowledge, Behaviours and Attitude. Using these elements as a measure of mathematical understanding could provide a better understanding of the effectiveness of mathematics support i.e. in terms of actual understanding rather than just performance. Also, using these elements to measure changes in mathematical thinking may provide a meaningful measure of effectiveness of mathematics support. The study of students' attitudes towards mathematics could be refined to better identify students' mathematical perspectives/beliefs. A more detailed collection of data and study of the methods of mathematics support used by the students and their *AtS* would give information on students' behaviours and again performance can be used to measure knowledge.

In conclusion this research has highlighted the benefits of mathematics support and the importance of reviewing and sharing practice. It has also seen the importance of student engagement with support. Further work is required to test the effectiveness of measurement models in different environments, nationally and internationally. It is envisaged the pressure HE practitioners face to protect the accessibility of education can be alleviated to some extent by the provision of research evidence based mathematics support.

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ACRONYMS

Acronym	In full
ASI	Approaches to Studies Inventory
ASSIST	Approaches and Study Skills Inventory
ASSIST+	Approaches and Study Skills Inventory Plus
AtS	Approaches the Studying
AtS_{Post}	*AtS* Post-intervention
AtS_{Pre}	*AtS* Pre-intervention
Attitude-1	Confidence in mathematics
Attitude-2	Liking for mathematics
Attitude-3	Past experience of mathematics learning
BMDT	Basic Mathematics Diagnostic Test
HE	Higher Education
HEI	Higher Education Institute
KAB	Knowledge, Attitudes and Behaviours
MASH	Maths and Statistics Help (Centre)
MEQ	Mathematics Entry Qualifications
MSC	Mathematics Support Centre
MSU	Mathematics Support Usage
Non-MSU	Non-Mathematics Support Usage
RGU	Robert Gordon University
SSC	Study Support Centre
UoS	University of Sheffield
DP-RI	Deep-Relating Ideas
DP-SM	Deep-Seeking Meaning
DP-UE	Deep-Use of Evidence
DP-PRP	Deep-Procedural Relating Processes
SR-LP	Surface-Lack of Purpose
SR-SB	Surface-Syllabus Boundness
SR-UM	Surface-Unrelated Memorising
SR-PMP	Surface-Procedural Memorising Processes
ST-AD	Strategic- Alertness to Assessment Demands
ST-OS	Strategic-Organised Studying
ST-TM	Strategic-Time Management

APPENDICES

Appendix 1 – Gibbons concepts for learning

Gibbons (2004) developed concepts help create the infrastructure for self-direction, self-motivation and self-assessment, such as, learning proposals, portfolios, and public presentations.

Teaching-learning environment: This term is used to describe the whole set of teaching, learning support, assessment and administrative arrangements, as well as the facilities and resources provided within a degree course. Our particular focus is on those aspects expected to influence most directly the quality of student learning.

*Constructive alignmen*t: This term is designed to capture the 'goodness-of-fit' between the aims of a course and the teaching-learning and assessment procedures followed; 'constructive' indicates that the aims involve a focus on developing conceptual understanding and ways of thinking and practising in the subject.

Ways of thinking and practising in the subject: Initial work suggested that a term was needed to cover not just approaches to studying, but also the thinking processes and subject-specific skills that staff are seeking to develop in their students. Deep approaches to studying which is well organised and applied with effort are being used to indicate engagement with the courses being studied.

Troublesome knowledge and threshold concepts: There is particular value in focusing on topics or ways of thinking that students find difficult, particularly when these act as a threshold to further learning. Examining these in relation to teaching and assessment provides a focused way of investigating influences on learning outcomes.

Appendix 2 – Variable attributes

	Total Number	Type of data	Mean	Median	Mode	SD	Minimum	Maximum	Range
MEQ Points	1028	Discrete	54.46	48.00	48	14.224	20	120	100
MEQ Grades[22]	1028	Grades	4.18	4.00	4	1.110	1	6	5
BMDT %	558	Percentages	57.95	60.00	55	15.818	0	94	94
BMDT Grades[23]	558	Grades	3.49	4.00	1				
BMDT Standardised[24]	558	Standardised	-0.000125	0.129599	-0.1865	1.0000252	2.2790	-3.5535	5.9426
Attitudes 1 (Confidence)	608	Likert	3.10	3.00	3	0.923	1	5	4
Attitude 2 (Liking)	597	Likert	3.27	3.00	3	1.014	1	5	4
Attitude 3 (Past)	594	Likert	3.57	4.00	4	0.855	1	5	4
Module Grades	645	Grades	4.18	4.00	4	1.110	1	6	5

Table 63 – Summary variable in RGU dataset

[22] Converted from the MEQ points using values in table 17
[23] Converted from BMDT Percentages using values in table 17
[24] BMDT Percentages were standardised by subtracting the mean of the BMDT percentages and the result was then divided by the standard deviation

	Total Number	Type of data	Mean	Median	Mode	SD	Minimum	Maximum	Range
MEQ Points	2040	Discrete	103.40	100.00	120	21.093	0	130	130
MEQ Grades[22]	2040	Grades	5.22	5.00	6	0.985	1	6	5
BMDT %	453	Percentages	81.48	84.00	87	15.499	0	100	100
BMDT Grades[23]	453	Grades	4.74	5.00	6	1.598	1	6	5
BMDT Standardised[24]	453	Standardised	-0.000205	0.3562	1.0000093	6.4520	-5.2571	1.1949	6.4520
Attitudes 1 (Confidence)	37	Likert	3.76	4.00	4	0.796	1	5	4
Attitude 2 (Liking)	37	Likert	4.14	4.00	5	0.976	1	5	3
Attitude 3 (Past)	37	Likert	3.70	4.00	4	0.909	1	5	4
Deep AtS – Pre	122	Discrete	15.3996	15.7500	15.50	2.66785	6.25	20.00	13.75
Surface AtS – Pre	122	Discrete	10.5000	10.0000	8.50	2.64419	4.50	19.00	14.50
Strategic AtS – Pre	122	Discrete	13.9795	14.5000	15.50	3.13564	5.00	20.00	15.00
Deep AtS – Post	25	Discrete	15.7200	16.0000	18.00	2.09205	12.00	19.00	7.00
Surface AtS – Post	25	Discrete	11.0400	11.0000	11.00	2.92233	4.00	17.00	13.00
Strategic AtS – Post	25	Discrete	13.6000	15.0000	15.00	3.77492	7.00	20.00	13.00
Module Marks	645	Marks	63.54	65.00	74.00	19.300	0	100	100
Module Grades[25]	645	Grades	4.62	5.00	6	1.531	1	6	5

Table 64 – Summary variable in UoS dataset

[25] Converted from Module Marks using values in table 17

Appendix 3 – RGU BMDT Questions

NUMERACY SECTION

10-Nu1 Addition of Negative Numbers

SG **1** Calculate: $(-3)+(-4)$

15-Nu1 Multiplication of Negative and Positive Numbers

SG **3** Calculate $4(-1.5)$

20-Nu1 Multiplication of Negative Numbers

SG **4** Calculate $(-3)(-5)$

25-Nu1 BODMAS 1

SG **5** Calculate $17 - 3 \times 4$

Note: ‘ $\times$ ’ means to **multiply**

30-Nu1 BODMAS 2

SG **2** Calculate: $18 + 6 \times (-1.5)$

Note: ‘ $\times$ ’ means to **multiply**

35-Nu1 Ratios

SG **6** Which of the following ratios is not equal to the others?

(a) 10:15

(b) 18:24

(c) 2:3

(d) 8:12

(e) -4:-6

40-Nu1 Factors of Integers

SG **7** Which of the following are true enter, for example, **abc**?

(a) 15 and 25 are both factors of 75

(b) 8 is a factor of 100

(c) 6, 8 and 16 are all factors of 48

(d) 5, 8 and 12 are all factors of 60

45-Nu2 Inequalities - Use of <,> signs

SG 8 Which of the following statements are true?

(a) $8.9 < 9.1$

(b) $-4 > -5.1$

(c) $2.5 < -13.6$

(d) $-3 < 7.7$

(e) $19.98 > 20.03$

50-Nu1 Size of Decimals

SG 9 Which is the largest of the following?

(a) 1/100

(b) 0.00099963

(c) 0.00997

(d) 0.01003

(e) 1/150

55-Nu1 Decimal Places

Correct 251.493

Enter the number 251.49251 rounded to 3 decimal places.

60-Nu2 Significant Figures

SG 11 Round -173.26148 to 4 **significant figures**.

65-Nu3 Scientific Notation

SG 12 We can write the number 0.00736 in the form

7.36 x 10^{n} (Scientific Notation).

What is the number **n**?

70-Nu2 Definition of Negative Powers

Enter (as a fraction) the number given by

$$\frac{3^{-2}}{2^{-3}}$$

75-Nu2 Cancellation of Numerical Fractions

SG 13 Cancel common factors to simplify $\frac{72}{90}$.

80-Nu1 Addition of Simple Fractions

SG 14 Calculate $\frac{1}{2}+\frac{3}{4}$

leaving your answer in its simplest form.

85-Nu2 Subtraction of Simple Fractions

SG 15 Calculate: $\frac{5}{6}-\frac{4}{5}$

Enter your answer in the **simplest** possible form.

90-Nu2 Order of Operations

SG 10 To calculate $\frac{12}{6 \times 3}$ you press a sequence of keys on your calculator.

Which one of the following would give the WRONG answer?

(a) $12 \div (6 \times 3)$
(b) $12 \div 6 \times 3$
(c) $(12) \div (6 \times 3)$
(d) $12 \div 6 \div 3$

ALGEBRA I SECTION

95-AI1 Collecting Terms Simple

SG 16 Collect terms in the following expression

$2x - 3y + 1 + y + 4x - 5$

leaving your answer in the simplest possible form.

100-AI2 Collecting Terms Advance

SG **17** Collect the terms in the following expression:

$2p - 4 + p^2 + 11p + 2 - 3p^2$

105-AI1 Evaluation of Simple Expression

SG **18** Evaluate: $2 + 3x$ if $x = 3$.

110-AI1 Addition of Negative Terms

SG **19** Simplify: $(2m + 5) - (m - 2)$

115-AI2 Expansion of Brackets - Simple

SG **20** Expand the bracket $2x(x - 3x^2)$

120-AI2 Factors of Algebraic Products

SG **21** Enter the other factor in the equation: $12x^3y = 3x^2(?)$

125-AI2 Simple Factorisation

SG **22** Factorise: $2z - 6z^2$

130-AI3 Difference of Squares

SG(c) **23** Factorise the following expression $4y^2 - 9$

135-AI2 Multiplication of Fractions

SG **24** What is $\frac{6}{y}$ x $\frac{y^2}{12}$?

Give your result in simplified form.

140-AI1 Solving Linear Equation I

SG **25** Solve the equation for x,
when $3x + 1 = 13$

145-AI2 Solving Linear Equation II

SG **26** Solve for C : $7-3c=-5c-4$

150-AI2 Evaluation of Formulae

SG **27** If $Q=p^2+2rt+1$ where p = 4, r = -2, t = 5,
What is Q?

155-AI2 Transposition of Formulae

SG **28** If c = 0.5ab then ***b* = ?**

Enter an expression for *b*.

ALGEBRA II SECTION

160-AII3 Division of Fractions

SG **29** If $12y$ is divided by $6y^2$.

Enter the result in its simplest form.

165-AII3 Expansion of Two Brackets

SG **30** Expand and collect terms: $(2+v)(3-v)$

170-AII3 Addition/Subtraction of Algebraic Fractions

SG(c) **31** Two fractions are put over a common denominator as shown:

$$\frac{3}{x+1}+\frac{2}{x+2}=\frac{?}{(x+1)(x+2)}$$

Enter the numerator (shown as **?**) in simplified form.

175-AII4 Lowest Common Denominator

SG(c) **32** When we wish to add two fractions, we put them over a lowest common denominator.

$$\frac{3}{x(x+1)}+\frac{2}{(x-1)^2}$$

Enter the **lowest common denominator** (in factorised form).

180-AII3 Simple Quadratic Equation

SG **34** Which one of the following statements about this quadratic equation are true? $x^2 + 4x = 0$

(a) has only one solution, x **= -4**

(b) has only one solution, x **= 4**

(c) has only one solution, x **= 0**

(d) has 2 solutions, x **= 0** and x **= -4**

(e) has 2 solutions, x **= 0** and x **= 4**

185-AII3 Factorising a Quadratic Function

SG **33** Factorise the following expression into two brackets

$x^2 - 2x - 15$ that is,

into the form $(x....)(x....)$.

190-AII3 Relationship of Roots and Factors

SG **36** The quadratic equation $x^2 + ax + b = 0$

has roots $x = -3$ and $x = 1$.

What are the values for ***a*** and ***b***?

195-AII3 Formula for Quadratic Equation

SG **37** If we solve the quadratic equation $x^2 - 6x + 4 = 0$ we obtain two solutions in the form $x = 3 \pm n$

What is the value of n ?

200-AII4 Completing the Square

SG/H **39** By completing the square put the expression $x^2 + 6x + 13$ into the form "$(....)^2 +$constant".

205-AII4 Polynomial Division

H **40** $(x - 3)$ is a factor of $f(x)$, where = $f(x) = 2x^3 + 3x^2 - 23x - 12$.
Express $f(x)$ in its fully factorised form.

210-AII4 Substitution in Formula

H **41** If $f(z) = z^2 - 2z$

What is $f(2z+3)$?

215-AII3 Number Patterns/Sequence

SG

35

x	1	2	3	4	5
y	2	4	6	8	10

The above sequence matches the function $y = 2x$.

Determine the function associated with the sequence below:

x	1	2	3	4	5
y	3	6	9	12	15

What is $y = ?$

220-AII3 Recurrence Relationships

H **42** A sequence is defined by the recurrence relation

$U_n = 0.5U_{n-1} + 2,\ U_1 = 3.$

Determine the value of U_3.

225-AII3 Equation of a Circle

H **43** A circle with radius 3 with centre at $x = 1,\ y = 0$

has equation **? = 9**

Enter the left-hand side of the equation.

230-AII4 Radius of a Circle

H **44** What is the radius of a circle with equation:

$x^2 - 4x + y^2 - 5 = 0$

235-AII4 Existence of Solutions

H **45** Which of the following has no solution?

(a) $3x = 5$ (b) $0x = -7$ (c) $4x = 0$ (d) $0x = 0$

240-AII3 Common Errors

SG/H 38 Which of the following statements are correct?

(a) $(x-1)^2 = x^2 + 1$

(b) $\frac{1}{x^2-x} = \frac{1}{x^2} - \frac{1}{x}$

(c) $\left(x + \frac{1}{x}\right)^2 = 2 + x^2 \frac{1}{x^2}$

(d) $x^2 + 2x - 8 = (x-4)(x+2)$

(e) $(-3x)^2 = -9x^2$

MISCELLANEOUS SECTION

245-Mi2 Percentages - Simple

SG 46 What is 20% of 60

250-Mi3 Percentages - Advance

SG 49 The value of a car is initially 1,000 pounds.

If the value decreases by 10%, then increases by 10%,

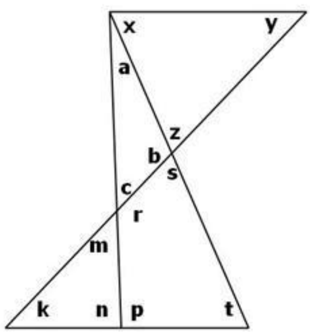
what is the final value?

255-Mi2 Unit Conversion

SG 48 Convert 1 metres per second to kilometres per hour.

260-Mi2 Triangle Angles

SG 50 Which of the following statements are **true**?



(a) $n + p = 180^\circ$

(b) $x + y + z = 180^\circ$

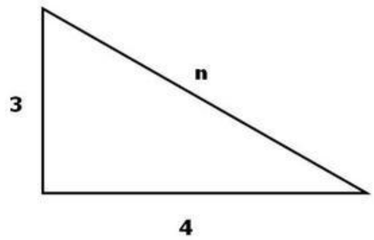
(c) $p + r + s + t = 180^\circ$

(d) $p + r + s + t + m + n + k = 180^\circ$

(e) $a + b + c + x + y + z = 360^\circ$

5-Mi2 Pythagoras Theorem

SG 51 Enter the number **n**



270-Mi2 Inverse Ratios

SG 47 If a car takes 5 hours for a journey travelling at
80 miles per hour (mph),
how many hours would it take if it travelled at 25 mph?

275-Mi2 Direct Variation

SG 52 The cost, £C of a taxi journey varies directly as the distance,
D miles, travelled. Given that a 10 mile journey costs £8.50.
Find the cost of a 17 mile journey.

280-Mi2 Joint Variation

SG 53 The number (N) of stamps which can be bought for a given sum
of money varies inversely as the price of each stamp (p pence).
Given that N = 5 when p = 12, find a formulae connecting N and p.

285-Mi2 Inverse Variation

SG 54 A musical note can be produced by blowing across the mouth of
an empty bottle. The frequency, f, of the note produced varies
as the diameter, d, of the mouth of the bottle and inversely as
the square root of the volume, V, of the bottle.
What is the relationship between f, d and V?

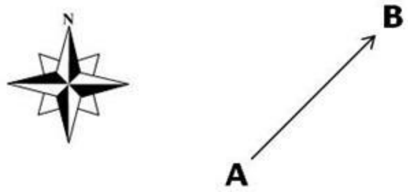
290-Mi3 Geometric Progression

H/SYS 58 A Geometric Progression has the first term **3**
and common ratio **-2.**
What is the **4-th term**?

295-Mi2 Bearings

SG 55

A ship is at point A and wants to sail to point B. What bearing should the ship sail on approximately?



300-Mi2 Set Notation

H 56 L=$\{$x: -2 $\le$ x $\le$ 3$\}$ and M=$\{$x: -4<x<2$\}$ where x $\in$ Z

Where 'Z' is the set of integers.

Which of the following statements describes $\mathrm{L} \cap \mathrm{M}$.

(a) $\{$-4, -3, -2, -1, 0, 1, 2, 3$\}$
(b) $\{$-3, -2, -1, 0, 1, 2, 3$\}$
(c) $\{$-3, -2, -1, 0, 1, 2$\}$
(d) $\{$-2, -1, 0, 1, 2$\}$
(e) $\{$-2, -1, 0, 1$\}$

305-Mi2 Vectors

H 57 If $\underline{u} = \begin{pmatrix} -3 \\ 3 \\ 3 \end{pmatrix}$ and $\underline{v} = \begin{pmatrix} 1 \\ 5 \\ -1 \end{pmatrix}$ Determine $\underline{u} + \underline{v}$.

310-Mi3 Complex Numbers

SYS 59 What is $(3+2j)-(4-3j)$?

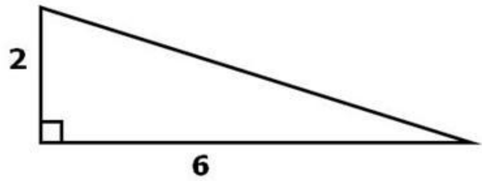
315-Mi4 Multiplying Complex Numbers

SYS 60 Calculate the product of complex numbers $(2+3j)(-1-4j)$
Simplify your answer.

PERIMETER, AREA AND VOLUME SECTION

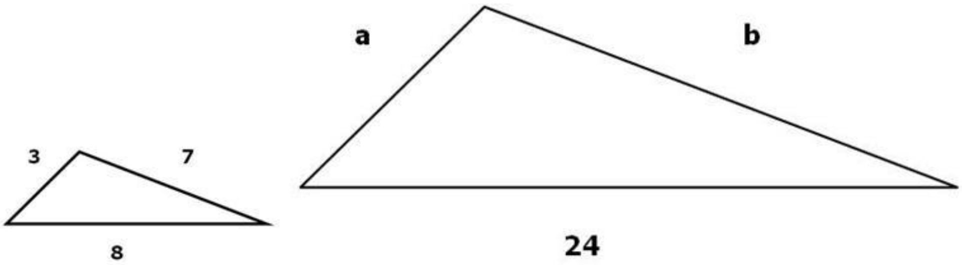
320-Pe1 Area of Triangle

SG 61 What is the area of the triangle shown?



325-Pe2 Similar Triangles - Length

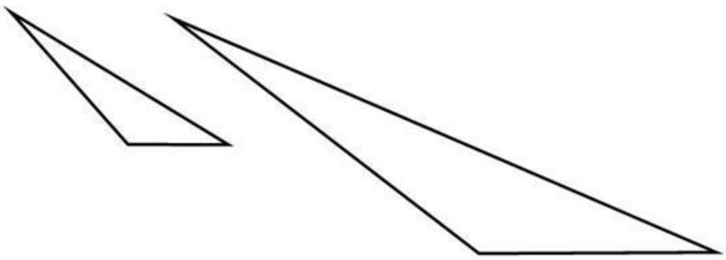
SG 62 We have two similar triangles as shown. Enter the lengths of sides **a** and **b**:



330-Pe3 Similar Trianlges Area/Length Relationship

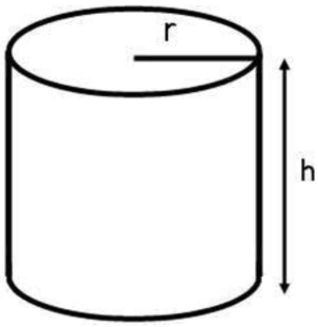
SG 65
We have 2 similar triangles as shown:

The ratio of the sides is 3:1. What is the ratio of their areas?



340-Pe4 Surface Area of Cylinder

SG 63
What is the **total** surface area of a cylinder with radius **r** and length **h** (including both ends)?



345-Pe3 Volume of Cylinder

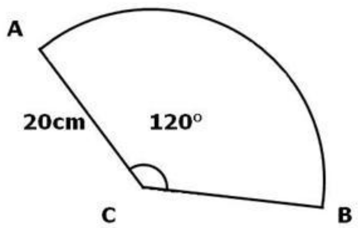
SG 64 What is the volume of a cylinder with radius r and height h?

350-Pe2 Circle Properties - Area

SG 66 What is the area of a circle with diameter d?

355-Pe2 Circle Properties - Arc Length

SG(c) 70
A fan is made from the sector of a circle centre C. Where the angle ACB = 120° and the radius of the circle is 20cm.
Calculate the length of the arc AB.



360-Pe4 Volume/Area/Length Relationships

SG(c) 67 If the dimensions of a cube are doubled which of these are true (for example, **a, b, c**)?

(a) the surface area is doubled

(b) the volume is 8 times as great

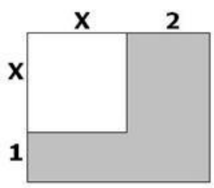
(c) the surface area is multiplied by 4

(d) the volume is multiplied by 16

(e) the volume is doubled

365-Pe3 Area of Irregular Shapes

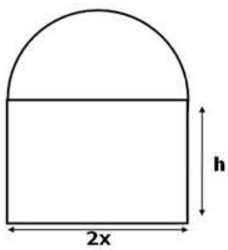
SG(c) 68
Find an expression for the area of the shaded part in terms of x?



370-Pe3 Perimeter

SG(c) 69
A window is in the shape of a rectangle surmounted by a semi-circle. The rectangle measures 2x metres by h metres.

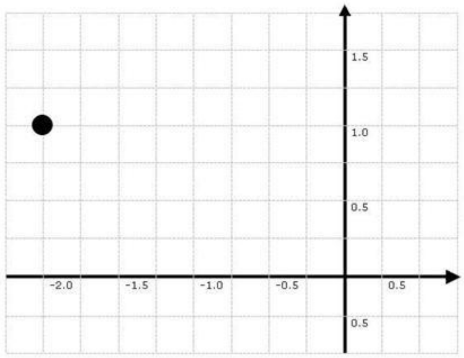
If the perimeter of the window is 10 m, **express 'h'** in terms of **x**.



GRAPHS SECTION

375-Gr1 Co-ordinates

SG 71
Enter the coordinates of the point:



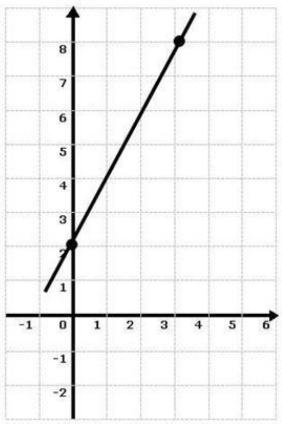
380-Gr2 Gradient of Straight Line

SG/H 72 What is the gradient of the line joining the points

(1, 2) and (3, 8)?

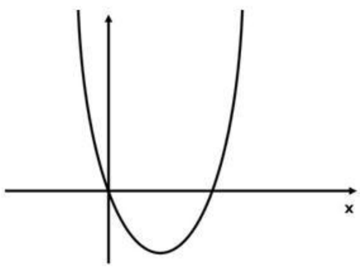
385-Gr3 Equation of a Straight Line

SG/H 73
The equation (in $\boldsymbol{x}$ and $\boldsymbol{y}$) of the straight line joining the points **(0, 2)** and **(3, 8).**
***y* = ?** Enter the right-hand side of the equation.



390-Gr4 Quadratic Graphs

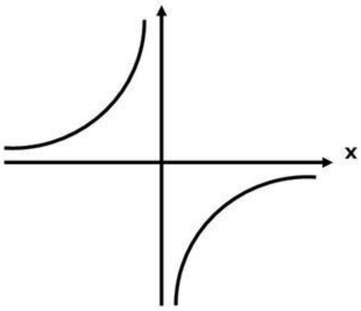
H 74 Choose the function whose graph looks like:



(a) $x^2 - x$
(b) $x^2 - 1$
(c) $(x - 1)^2$
(d) $x^2 + x$
(e) $1 - x^2$

395-Gr4 Reciprocal Graphs

H **75** Which of the following are represented by this graph:



(a) $-\frac{1}{x}$

(b) $\frac{1}{x}-1$

(c) $1+\frac{1}{x}$

(d) $1-x^2$

(e) $1-\frac{1}{x}$

EQUATIONS SECTION

400-Eq3 Solving Simple Inequalities

SG **76** The following inequality can be solved to give: $x < a$

$3-2x < 4-3x$

What is the value of a ?

405-Eq3 Simultaneous Equations

SG **77** Solve the simultaneous equations

$$2x+3y=12$$
$$3x+4y=17$$

(Enter the values for both X and y e.g. -2, 4)

410-Eq3 Unusual Linear Equation I

Solve $\frac{3}{y}=\frac{6}{y}+2$

415-Eq3 Unusual Linear Equation II

SG **78** Solve $\frac{3}{y}=\frac{5}{(y-1)}$

420-Eq4 Difficult Linear Equation

SG **79** Solve for T in terms of a . $\frac{2T-1}{1-3T}=a$

425-Eq4 Solutions of a Quadratic Equation

H **80** How many real solutions are there to the equation

$x^2+3x+4=0$

430-Eq4 Solution of a Quadratic by Completing the Square

Question 406 Solution of quadratic by completing the square

H **81** If we solve $p^2 - 4p - 21$ by completing the square,

we obtain an answer in the form $(p-a) = \pm b$.

What is b ?

POWERS SECTION

435-Po4 Arbitrary Factors

SG **82** In the following, the factor W^3 has been taken out of the left-hand side to give the right-hand side:

$$4W^2 + W^3 = W^3(1 + 4W^n)$$

Enter the value of the number n .

440-Po1 Definition of Square Roots

SG **84** What is the value of $\sqrt{16}$.

445-Po1 Definition of Positive Powers

SG **83** Enter the value of 3^3.

450-Po2 Rules for Positive Powers

SG **87** If $\frac{x^n}{x^4} = x^2$

what is the number n ?

455-Po1 Definition of Negative Powers

SG(c) **85** Enter (as a fraction) the number given by 3^{-2} .

460-Po3 Rules for Negative Powers

SG **86** If $p^{-3}.p^{-4} = p^n$.

What is the value of n?

465-Po3 Definition of Fractional Powers

SG(c) 88 Give the value of $8^{\frac{1}{3}}$.

470-Po3 Rules for Fractional Powers

SG(c) 90 If $p^{\frac{1}{2}}.p^{\frac{1}{3}} = p^n$.

What is the value of n ?

475-Po4 Simplify + Scientific notation

SG(c) 89 $\frac{-2.5 \times 10^{-2}}{0.2 \times 10^{-3}} = -1.25 \times 10^n$ What is the value of n ?

480-Po2 Surds Properties - Simple

SG(c) 91 Express $\sqrt{3} + \sqrt{48}$ as a surd in its simplest form i.e. $a\sqrt{b}$.

485-Po3 Surds Properties - Advance

SG(c) 92 Given the expression $\frac{\sqrt{3}+\sqrt{48}}{\sqrt{3}-1}$,

rationalise and express in the simplest form i.e. $\alpha + \sqrt{\beta}$

490-Po3 Simplify - Fractions and Powers

SG/H 93 Express the following in its simplest form

(without powers) fraction $\frac{4^{-2}2^6}{2^{-3}4^3}$.

495-Po4 Logarithms

H 94 If log 4 - 2 log 6 = log x give the number x as a fraction.

<u>STATISTICS SECTION</u>

500-St2 Range

SG 95 What is the **range** of the discrete data

[8.4 3 -5 1.5 -1 -2 8.3]

505-St2 Mean

SG **96** What is the **average** (mean) of the numbers
[2 8 3 -4 9]

510-St2 Mode

SG **97** What is the modal of the set of numbers?

[1 8 9 4 3 5 3 6 3 11 4]

515-St2 Median

SG **98** What is the median of the set of numbers?

[8 12 4 5 6 2 2]

520-St2 Upper Quartile

SG **99** What is the upper quartile of the set of numbers?

[1 2 3 3 5 7 7]

525-St2 Probability-dice

SG **100** A fair dice is rolled.

What is the probability of obtaining a ‘6’?

530-St2 Probability-coins

SG **101** A fair coin is tossed **twice** with equal probability of

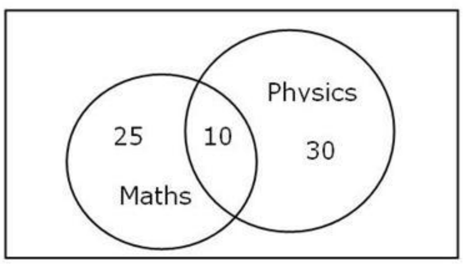
'head' or 'tail'.

What is the probability of obtaining

one head and one tail in any order?

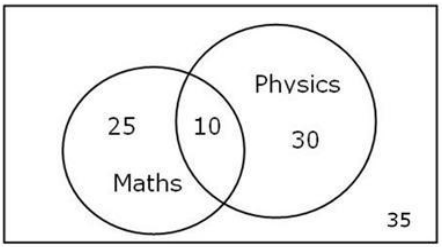
535-St2 Probability - Venn Diagrams

H **102**
The number of students on a course with both, one or neither of A-level Mathematics and A-level Physics is shown by the diagram below.
What is the probability that a randomly chosen student has only one of these?



540-St2 Conditional Probability - Venn Diagrams

H 103
The number of students on a course with one, both or neither of A-level Mathematics and A-level Physics is shown by the diagram below.
If a randomly chosen student has A-level Physics what is the probability he/she has A-level Mathematics?



TRIGONOMETRY SECTION

545-Tr2 Supplementary Angles

SG 104 Which of the following expressions is positive?

(a) $\cos(120^\circ)$ (b) $\sin(120^\circ)$ (c) $\tan(120^\circ)$

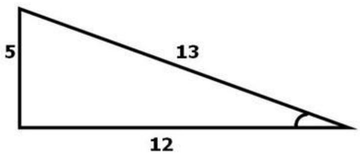
550-Tr2 Complementary Angles

SG/H 109 If A is between 0 and 90 degrees, which of the following complementary angle statements are true?

(a) $\sin(A-90)^0 = \cos(A)^0$
(b) $\sin(A-90)^0 = \sin(A)^0$
(c) $\cos(A-90)^0 = \sin(A)^0$
(d) $\cos(A-90)^0 = \cos(A)^0$

555-Tr2 Sine Ratio of an Angle

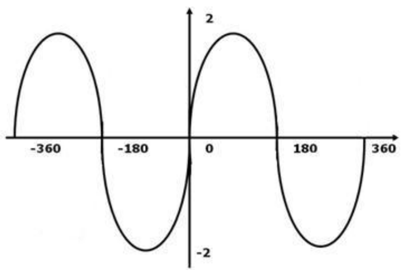
SG 105
Enter the Sine ratio of the angle



560-Tr2 Trigonometric Graphs

SG 106
Given the following graph which function does it represent?

(a) $f(x) = \sin x$
(b) $f(x) = \cos x$
(c) $f(x) = \cos 2x$
(d) $f(x) = 2\sin x$



565-Tr3 Sine/Cosine Relationships

SG/H 108 Which of the following statements are true for all values of x.

(a) $\sin^2 x + \cos^2 x = 1$
(b) $\sin 2x + \cos 2x = 1$
(c) $\sin x + \cos x = 1$
(d) $(\sin x)^2 + (\cos x)^2 = 1$
(e) $\sin x^2 + \cos x^2 = 1$

570-Tr2 Advanced Trigonometric Formulae I

SG/H 107 Which of the following statements are true?

(a) $\cos(-A) = -\sin(A)$
(b) $\cos(-A) = \sin(A)$
(c) $\cos(-A) = \cos(A)$
(d) $\cos(-A) = -\cos(A)$

575-Tr2 Advance Trigonometric Formulae II

SG/H 110 What is the maximum value of $\frac{1}{3} Sin\left(\theta - \frac{4\pi}{5}\right)$

580-Tr4 Sine and Cosine Functions

SG/H 112 What is the period of the function $\cos(4x)$?
(hint π should appear in your answer)

585-Tr2 Special Angles

SG/H 111 Given that $\cos 45^\circ = \dfrac{1}{\sqrt{2}}$ and $\tan 45^\circ = 1$.

What is the value of $\sin 45^\circ$?

590-Tr2 Standard Angles

H **115** Given that $\sin\theta = \dfrac{1}{2}$, $\cos\theta = \dfrac{\sqrt{3}}{2}$ and $\tan\theta = \dfrac{1}{\sqrt{3}}$

what is the value of θ ?

595-Tr3 Degrees-Radians

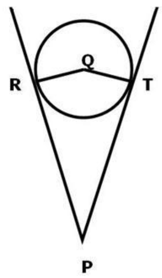
H **113** What is the value of 135° in radians?

560-Tr3 Radians-Degrees

H **114** Express the angle $\frac{\pi}{6}$ radians in degrees.

565-Tr2 Circle Properties – Angles

H **116**
PT and PR are tangents at T and R to the circle, centre O TQR = 150°.
Which of the following represent the angle TPR.



(a) 15°
(b) 30°
(c) 75°
(d) 105°
(e) 210°

<u>CALCULUS SECTION</u>

570-Ca3 Differentiate Powers

H **117** Differentiate x^3 with respect to X **.**

575-Ca3 Max/Min of Quadratics

H **118** What value of X gives the **minimum** of the function

$f(x) = 3x + x^2$?

580-Ca4 Product Rule

SYS **121** Differentiate $x.e^x$.

585-Ca4 Integrate Powers I

H **119** If $\frac{dy}{dt} = 2t^3$ find an expression for **y**.

590-Ca4 Integrate Powers II

H **120** If $\frac{dy}{dx} = 2x^3$ and given that $y = 0$ when $x = 0$,

which of the following represents the function for y ?

a) $\frac{x^4}{2}$ b) $\frac{3x^4}{2}$ c) x^2 d) $2x^2$

Appendix 4 – RGU BMDT Student Profile Questions

Age: .... Matriculation No.: .... Date: ....

Past Mathematics Qualification

Please select:
1 Scottish Higher; 2 Standard Grade;
3 A or AS Level; 4 CSYS;
5 GCSE; 6 Vocational (e.g. BTEC);
7 Overseas qualific'n; 8 Access/Found. Year;
9 No mathematics qualific'n;
x Other, Please specify: ....

Grade and Year: ....

Which word best describes your past experience of mathematics?

Please select:
(a) Excellent;
(b) Good;
(c) Fair;
(d) Bad;
(e) Very Bad.

Which word best describes your ability in mathematics?

Please select:
(a) Exceptional;
(b) Good;
(c) Adequate;
(d) Less than adequate;
(e) Poor.

Which best describes your feelings for mathematics?

Please select:
(a) Find it interesting;
(b) Find it enjoyable it;
(c) Indifferent;
(d) Don't find it enjoyable;
(e) Don't find it interesting.

Appendix 5 – UoS BMDT Questions

Mathematics Diagnostic Test - Engineering 09/10

1. **NuL1-145 BODMAS 2b**

   Calculate -9+5*(-5+4)

   (Note: * means multiply)

2. **NuL1-150 Ratios**

   Which of the following ratios is not equal to the others?

- *10:15*
- *18:24*
- *8:12*
- *2:3*
- *-4:-6*
- *Don't know*

3. **NuL1-160 Factors of Integers**

   Which of the following are true?

- *5,8 and 12 are all factors of 60*
- *6, 8 and 16 are all factors of 48*
- *15 and 25 are both factors of 75*
- *8 is a factor of 100*
- *Don't know*

4. **NuL1-190 Addition of Simple Fractions**

   Calculate the following expression: 1/2 + 3/4

   Give your answer in its simplest fraction using / e.g. 2/5

5. **NuL2-215 Sigma Notation**

   What is the solution of the sigma function?

$$\sum_{n=1}^{3} 2n$$

6. NuL2-220 Inequalities - Use of <, > signs

Which of the following statements are true?

A. $-4 > -5.1$

B. $19.98 > 20.03$

C. $8.9 < 9.1$

D. $2.5 < -13.6$

E. $-3 < 7.7$

F. Don't know

7. NuL2-240 Unit Conversion

Convert 1 metres per second to kilometres per hour.

Give your answer correct to 1 decimal place

8. NuL2-270 Cancellation of Numerical Fractions

Cancel common factors to simplify:

72/90

Input fractions using / e.g. 2/5

9. NuL2-280 Subtraction of Simple Fractions

Calculate the following expression: 5/6 - 4/5

Leaving your answer in its simplest form (fractions using / e.g. 2/5)

10. NuL3-310 Percentages – Advance

The value of a car is initially 1,000 pounds.

If the value decreases by 10%, then increases

by 10%, what is the final value?

11. NuL3-330 Scientific Notation

We can write the number 0.00736 in the form

7.36×10^{n} (scientific notation).

What is the value of n?

12. AlgL2-210 Collecting Terms - Advance

Collect the terms in the following expression

$2p - 4 + p^2 + 11p + 2 - 3p^2$.

And select correct simplified result:

A. $2p^2 + 3p + 6$

B. $-2p^2 + 13p - 2$

C. $p^2 + 13p - 6$

D. $4p^2 + 13p - 2$

E. Don't know

13. AlgL2-220 Expansion of Brackets – Simple

Expand the bracket $2x(x-3x^2)$.

Which expression gives the correct answer?

A. $2x + 6x^2$

B. $2x^2 - 5x^3$

C. $2x - 6x^3$

D. $2x^2 - 6x^3$

E. Don't know

14. EqL1-120 Solving Linear Equation - Simple 1

Solve the equation for x

when $3x + 1 = 13$.

15. EqL1-125 Solving Linear Equation - Simple 2

Solve for c:

When $7 - 3c = -5c - 4$.

Input fractions using / e.g. 2/5

16. AlgL2-230 Factors of Algebraic Products

Enter the factor (?) in the equation:

$12x^3y = 3x^2(?)$.

17. AlgL2-240 Simple Factorisation

Factorise: $2z - 6z^2$

18. AlgL2-250 Multiplication of Fractions

Simplify the following equation.

$$\frac{6}{y} \times \frac{y^2}{12}$$

Enter fractions using the forward slash / e.g. 3/5.

19. AlgL2-260 Evaluation of Formulae

If $Q = p^2 + 2rt + 1$

where $p = 4$, $r = -2$, $t = 5$,

What is Q?

20. AlgL3-315 Difference of Squares

Factorise the following expression $4y^2 - 9$?

21. AlgL3-340 Expansion of Two Brackets

Expand and collect terms:$(2 + v)(3 - v)$

Which expression gives the correct answer?

A. $-v^2 + v + 6$
B. $-2v^2 + v + 5$
C. $6 + v^2 + v$
D. $2v^2 + v - 6$
E. Don't know

22. AlgL3-360 Factorising a Quadratic Function - Simple 1

Factorise the following expression into two brackets: $x^2 - 2x - 15$

that is, into the form (x...)(x...).

23. EqL3-350 Unusual Linear Equation 1

Solve the following equation.

$$\frac{3}{y} = \frac{6}{y} + 2$$

24. EqL3-355 Unusual Linear Equation 2

Solve the following equation.

$$\frac{3}{y} = \frac{5}{(y-1)}$$

Input fractions by using the forward slash / e.g. 3/5.

25. EqL3-340 Simultaneous Equations

Solve the simultaneous equations

$2x + 3y = 12$

$3x + 4y = 17$

Enter the values for x and y as x, y e.g. -2, 4

26. EqL5-510 Solutions of a Quadratic Equation3

Solve the following for x by factorisation.

$3x^2 - 7x + 2 = 0$

Input fractions by using / e.g. 2/5 and separate answers using comma and space

27. AlgL4-420 Completing the Square

By completing the square put the expression

$X^2 + 6x + 13$ into the form " (...)^2 + constant ".

Select the correct answer:

A. $(x+3)^2 + \sqrt{13}$
B. $(x+3)^2 + 13$
C. $(x+3)^2 + 7$
D. $(x+3)^2 + 4$
E. Don't know

28. InL1-120 Definition of Positive Powers

What is the value of 3^3?

29. InL2-210 Rules for Positive Powers

What is the value of n if

$$\frac{x^n}{x^4} = x^2$$

30. InL3-310 Rules for Negative Powers

What is the value of n, if $p^{-3} * p^{-4} = p^n$?

* means multiply

31. InL3-320 Definition of Fractional Powers

Give the value of $8^{1/3}$

32. InL4-430 Logarithms

If log 4 - 2 log 6 = log x give the number x as a fraction.

Input fractions by using / e.g. 2/5

33. InL4-440 Indices to Logs 1

Find the value of x in

$3.6^x = 9.7$

Give your answer correct to 2 decimal places.

34. AlgL3-310 Complex Numbers

What is the result of (3 + 2j) - (4 - 3j)?

35. AlgL4-450 Multiplying Complex Numbers

Calculate the product of complex numbers

(2 + 3j)(-1 - 4j)

Simplify your answer.

36. DfL3-310 Differentiate Polynomials 1

Differentiate x^3 with respect to x.

Select the correct answer:

A. $2x^2$

B. $x^2/2$

C. $x^2/3$

D. $3x^2$

E. Don't know

37. DfL4-410 Differentiating Trigonometric Function – Simple

Evaluate

$$\frac{dy}{dx}$$

when y=2sin2x.

38. DfL4-420 Differentiating Exponential Function

Evaluate

$$\frac{dy}{dx}$$

when $y=e^{3x}$ and x=1.

Give your answer correct to 1 decimal place.

39. ItgL4-420 Integrate Powers 2a

If dy/dx=2x3 and given y=0 when x=0.

Find an expression for y.

Select the correct answer:

A. $x^4/2$

B. x^4

C. $2x^2$

D. $3x^4/2$

E. Don't know

40. ItgL4-440 Definite Integrate 1

Evaluate the definite integral

$$\int_0^2 x^3\,dx$$

Appendix 6 – RGU - Individual Learning Programme

Matriculation Number	…………
Student name	…………
First name	…………
Gender	M
Age Group	18
Group	BEng EEE
MathematiCsys Qualification	Overseas
Grade and Year	
Confidence in Mathematical Ability	b
Feelings for Mathematics	a
Past Experience of Mathematics	b
Date taken (d m yr)	29/09/1999

Total out of 68	14
Percentage	28%
Numeracy	44%
Algebra 1	67%
Algebra 2	14%
Miscellaneous	80%
Perimeter Area & Volume	25%
Powers	00%
Statistics	00%
Trigonometry	00%
Calculus	00%

	SKILLS YOU HAVE DIFFICULTIES WITH			WORKSHEETS TO COMPLETE:	
Q	Skill	Q	Skill	W/S	W/S
1	Simple calculation/Negative*Positive	35	Unit Interrelationships	N1	N48
2	Negative Numbers	40	Equation of a Straight Line	N2	N49
4	Ratios	41	Sets	N3	N52
6	Size of decimals/Use of < & >	42	Area of a Triangle	N4	N56
7	Simple fractions/+/- numerical fractions	43	Perimeter	N5	
13	Transpose Formula	44	Circle Properties	N7	C1
15	Difference of Squares	48	Positive Powers - Rules	N8	C2
17	+/- Algebraic Fractions/L.c.d of Algebraic Fractions	49	Positive Powers - Definition/Simplify fractional powers	N9	C4
18	Simple Quadratic Equations	50	Fractional Powers - Definition	N10	C6
19	Quadratic roots & factors	53	Factors - Algebraic/Expand …(…)	N12	C7
21	Simultaneous Equations	54	Range of a Set of numbers	N14	C8
22	Use Quadratic Formula	55	Mean of a Set of numbers	N18	C14
26	Algebraic Substitution	58	Complementary/Supplementary Angles	N22	C17
29	Inverse Ratios	59	Special/Standard Angles	N23	C24
31	Multiply Complex Numbers	61	Definition of Radians	N24	C27
		62	Circle Properties	N25	C29
		63	Trig. Functions	N26	C30
		64	Sine/Cos as Functions	N28	C43
		65	Differentiation - Simple	N30	C50
		66	Max./Min. of a Quadratic	N31	
		67	Differentiation - Product Rule	N32	
		68	Integration - Simple	N33	
				N37	
				N38	
				N40	
				N46	

Appendix 7 – UoS Individual Learning Programme

Mathematics Diagnostic Test – FCE 2009
Revision Programme

	Name:*********** *****	ID: ********	Course: MASH Diagnostic Test EEE 2009	
	Time spent: 01:04:09	Started: 22/09/2009 14:44:00	Submitted: 22 September 2009 15:48	Total score: 75.0%

Scores by Topics

Number Skills Score	83.3%	Factorisation Score	50.0%
Notation Score	100.0%	Indices Score	100.0%
Linear Equations Score	75.0%	Logarithms Score	50.0%
Quadratic Equations	100.0%	Complex Numbers Score	50.0%
Algebra Score	100.0%	Differentiation Score	33.3%
Fractions Score	50.0%	Integration Score	100.0%

Results by Questions

1 BODMAS	Correct	21 Expansion of Two Brackets	Correct
2 Ratios	Correct	22 Factorising a Quadratic Function	Correct
3 Factors of Integers	Please Revise	23 Unusual Linear Equation 1	Correct
4 Addition of Simple Fractions	Correct	24 Unusual Linear Equation 2	Please Revise
5 Sigma Notation	Correct	25 Simultaneous Equations	Correct
6 Inequalities - Use of <, > signs	Correct	26 Solutions of a Quadratic Equation3	Correct
7 Unit Conversion	Correct	27 Completing the Square	Correct
8 Cancellation of Numerical Fractions	Please Revise	28 Definition of Positive Powers	Correct
9 Subtraction of Simple Fractions	Correct	29 Rules for Positive Powers	Correct
10 Percentages – Advance	Correct	30 Rules for Negative Powers	Correct
11 Scientific Notation	Correct	31 Definition of Fractional Powers	Correct
12 Collecting Terms - Advance	Correct	32 Logarithms	Please Revise
13 Expansion of Brackets – Simple	Correct	33 Indices to Logs 1	Correct
14 Solving Linear Equation - Simple 1	Correct	34 Complex Numbers	Correct
15 Solving Linear Equation - Simple 2	Correct	35 Multiplying Complex Numbers	Please Revise
16 Factors of Algebraic Products	Correct	36 Differentiate Polynomials 1	Correct
17 Simple Factorisation	Please Revise	37 Differentiating Trig Function	Please Revise
18 Multiplication of Fractions	Please Revise	38 Differentiating Exp Function	Please Revise
19 Evaluation of Formulae	Correct	39 Integrate Powers 2a	Correct
20 Difference of Squares	Please Revise	40 Definite Integrate 1	Correct

Appendix 8 – RGU BMDT Test Questions

RGU_BMDT_A	RGU_BMDT_B	RGU_BMDT_C
002BODMAS	001NegativeNumbers	001NegativeNumbers
003Negative*Positive	003Negative*Positive	002BODMAS
004MultplyingNegatives	004MultplyingNegatives	003Negative*Positive
005BODMAS	005BODMAS	004MultplyingNegatives
006Ratios	006Ratios	005BODMAS
007Factors	007Factors	006Ratios
008Inequalities	008Inequalities	007Factors
009SizeofDecimals	009SizeofDecimals	008Inequalities
010Precedencerules	010Precedencerules	009SizeofDecimals
011Significantfigures	011Significantfigures	010Precedencerules
012ScientificNotation	012ScientificNotation	011Significantfigures
013Simplifyingfractions	013Simplifyingfractions	012ScientificNotation
014Addingfractions	014Addingfractions	013Simplifyingfractions
015SubtractingFractions	015SubtractingFractions	014Addingfractions
016Collectingterms(linear)	016Collectingterms(linear)	015SubtractingFractions
017CollectingTerms	017CollectingTerms	016Collectingterms(linear)
018Evaluatingsimpleexpressions	018Evaluatingsimpleexpressions	017CollectingTerms
019Expandingandsimplifyingbrackets	020Expanding()	018Evaluatingsimpleexpressions
020Expanding()	021Algebraicfactors	019Expandingandsimplifyingbrackets
021Algebraicfactors	022Simplefactorisation	020Expanding()
022Simplefactorisation	023DifferenceofTwoSquares	021Algebraicfactors
023DifferenceofTwoSquares	024Multiplyingfractions	022Simplefactorisation
024Multiplyingfractions	025SimpleLinearEquarion	023DifferenceofTwoSquares
025SimpleLinearEquarion	026LinearEquarions	024Multiplyingfractions
026LinearEquarions	027Evaluatingformulae	025SimpleLinearEquarion
027Evaluatingformulae	028Transposition	026LinearEquarions
028Transposition	029DividingAlgebraicFractions	027Evaluatingformulae
029DividingAlgebraicFractions	030Expandingdoublebrackets	028Transposition
030Expandingdoublebrackets	031Adding/SubtractingAlgebraicFractions	029DividingAlgebraicFractions
031Adding/SubtractingAlgebraicFractions	032LowestCommonDenomi9tor	030Expandingdoublebrackets
032LowestCommonDenom	033Factorisingquadratics	031Adding/SubtractingAlgebraicFractions
033Factorisingquadratics	034Simplequadraticequations	033Factorisingquadratics
034Simplequadraticequations	036Quadraticroots&factors	034Simplequadraticequations
035Creatingsimpleformulae	037QuadraticFormula	035Creatingsimpleformulae
036Quadraticroots&factors	041AlgebraicSubstitution	036Quadraticroots&factors
037QuadraticFormula	045Equationswithnosolutions/divisionbyzero	037QuadraticFormula
038Commo9lgebraicErrors	046Percentages	039Completingthesquare

RGU_BMDT_A	RGU_BMDT_B	RGU_BMDT_C
039Completingthesquare	049AdvancedPercentages	046Percentages
040FactorisingPolynomials	050Angleswithincompositeshapes	047Speed,Distance,Time
041AlgebraicSubstitution	051Pythagoras	048UnitConversions
042Recurrencerelations	053InverseVariation	049AdvancedPercentages
043Equationofacircle	061Areaofatriangle	050Angleswithincompositeshapes
044Deduceradiusofacircle	062Similarshapes	051Pythagoras
045Equationswithnosolutions/divisionbyzero	063SurfaceArea	057AddingvectorsII
046Percentages	064Volumeofacylinder	058GeometricSequence
047Speed,Distance,Time	065Length,AreaVolumeRatios	061Areaofatriangle
048UnitConversions	066AreaofaCircle	070PropertiesofaCircle
049AdvancedPercentages	067Length,AreaVolumeRatios	072Gradientofastraightline
050Angleswithincompositeshapes	068AreaofanIrregularshape	074IdentityofaQuadraticfunction
051Pythagoras	071CartesianCoordi9tes	075IdentityofaReciprocalfunction
052DirectVariation	072Gradientofastraightline	076Solvinginequations
053InverseVariation	073Equationofastraightline	077SimultaneousEquations
054JointVariation	076Solvinginequations	081Solvingquadraticsbycompletingthesquare
055Bearings	077SimultaneousEquations	082Arbitraryfactors
056AddingvectorsI	078Difficultlinearequations	083CubicNumbers
057AddingvectorsII	079Transposition	086Negativepowers
058GeometricSequence	082Arbitraryfactors	088Evaluatingfractio9lpowers
059Subtractingvectors	083CubicNumbers	092 Further Surds
060Multiplyingcomplexnumbers	085Evaluatingnegativepowers	096Meanofasetofdata
061Areaofatriangle	086Negativepowers	098Medianofasetofdata
062Similarshapes	087PositivePowers	100Simpleprobability
063SurfaceArea	088Evaluatingfractio9lpowers	104Positive/NegativeTrigExpressions
064Volumeofacylinder	089Simplifyingscientificnotation	105Trigratios
065Length,AreaVolumeRatios	090Fractio9lPowers	106IdentifyingTrigGraphs
066AreaofaCircle	093Indices	112PeriodofaTrigExpression
067Length,AreaVolumeRatios	094Logarithms	
068AreaofanIrregularshape	108TrigFormulae	
069PerimterofanIrregularshape	117SimpleDifferentiation	
070PropertiesofaCircle		
071CartesianCoordi9tes		
072Gradientofastraightline		
073Equationofastraightline		
074IdentityofaQuadraticfunction		
075IdentityofaReciprocalfunction		
076Solvinginequations		
077SimultaneousEquations		
RGU_BMDT_A	**RGU_BMDT_B**	**RGU_BMDT_C**
078Difficultlinearequations		
079Transposition		
080Solutionofaquadratic		

081Solvingquadraticsbycompletingthesquare
082Arbitraryfactors
083CubicNumbers
084SquareRoots
085Evaluatingnegativepowers
086Negativepowers
087PositivePowers
088Evaluatingfractio9lpowers
089Simplifyingscientificnotation
090Fractio9lPowers
092 Further Surds
093Indices
094Logarithms
095Rangeofasetofdata
096Meanofasetofdata
097Modeofasetofdata
098Medianofasetofdata
099Upperquartileofasetofdata
100Simpleprobability
101Combinedprobabilities
102VenndiagramprobabilityI
103VenndiagramprobabilityII
104Positive/NegativeTrigExpressions
105Trigratios
106IdentifyingTrigGraphs
107SimpleTrigIdentities
108TrigFormulae
111TrigRatios
112PeriodofaTrigExpression
113Convertingdegreesintoradians
114Convertingradianstodegrees
115Trigratios
116Anglesoftangentstoacircle
117SimpleDifferentiation
118Statio9ry/TurningPoints
119IndefiniteIntegraion
120DefiniteIntergration

Appendix 9 – UoS BMDT Test Questions

Q#	Qname
1	BODMAS
2	Ratios
3	Factors of Integers
4	Addition of Simple Fractions
5	Sigma Notation
6	Inequalities - Use of <, > signs
7	Unit Conversion
8	Cancellation of Numerical Fractions
9	Subtraction of Simple Fractions
10	Percentages – Advance
11	Scientific Notation
12	Collecting Terms - Advance
13	Expansion of Brackets – Simple
14	Solving Linear Equation - Simple 1
15	Solving Linear Equation - Simple 2
16	Factors of Algebraic Products
17	Simple Factorisation
18	Multiplication of Fractions
19	Evaluation of Formulae
20	Difference of Squares
21	Expansion of Two Brackets
22	Factorising a Quadratic Function -Simple 1
23	Unusual Linear Equation 1
24	Unusual Linear Equation 2
25	Simultaneous Equations 1
26	Simultaneous Equations 2
27	Solutions of a Quadratic Equation3
28	Completing the Square
29	Definition of Positive Powers
30	Rules for Positive Powers
31	Rules for Negative Powers
32	Definition of Fractional Powers
33	Logarithms
34	Indices to Logs 1
35	Differentiate Polynomials 1
36	Differentiating Trigonometric Function
37	Differentiating Exponential Function
38	Integration Simple
39	Integrate Powers 2a
40	Definite Integrate 1

Q#	Qname
1	BODMAS
2	Ratios
3	Factors of Integers
4	Addition of Simple Fractions
5	Sigma Notation
6	Inequalities - Use of <, > signs
7	Unit Conversion
8	Cancellation of Numerical Fractions
9	Subtraction of Simple Fractions
10	Percentages – Advance
11	Scientific Notation
12	Collecting Terms - Advance
13	Solving Linear Equation - Simple 1
14	Solving Linear Equation - Simple 2
15	Factors of Algebraic Products
16	Simple Factorisation
17	Multiplication of Fractions
18	Evaluation of Formulae
19	Expansion of Brackets – Simple
20	Definition of Positive Powers

Appendix 10 – UoS Student feedback questionnaire

Maths and Statistics Help Service (MASH)
Student feedback questionnaire

The University of Sheffield Maths and Statistics Help service (MASH) provides one-to-one support and resources for all students at the University of Sheffield. The University is interested in student awareness of the service, and its impact on any students who have made use of it. The following questions will take no more than five minutes, and will provide valuable information for publicising and developing MASH so that it can better support students studying maths and statistics. All answers are anonymous. Data will be used internally by the University, and may be used for external publication. The questionnaire will close on [Friday 20 February?].

1) About you:
   a) Male/female
   b) Year of study
   c) Degree programme
   d) UK student/EU student/international student

2) [Awareness of MASH] Please indicate the statement below that best describes your awareness of the Maths and Statistics Help (MASH) service.
   a) I did not know that the University of Sheffield had a Maths and Statistics Help service. [skip to Q5]
   b) I knew that the University of Sheffield has a Maths and Statistics Help service, but I have not visited it.
   c) I have had support from the University of Sheffield Maths and Statistics Help service. [skip logic to Q6]

3) [Question to produce data on where heard about service – note that we already have this data for users] How did you become aware of MASH? (select all options that apply)
   a) Poster
   b) Postcard
   c) Email
   d) Word of mouth
   e) MASH Tutor
   f) Member of teaching staff
   g) Another student
   h) Other (please state)

4) Why haven't you made use of MASH (select all options that apply)
   a) I do not need any support in maths and/or statistics
   b) I do not know what sort of support is offered by MASH
   c) I would like support from MASH, but I don't know where the service is based
   d) I would like support from MASH, but I don't know what time it is open
   e) I would like support in maths and/or statistics, but MASH don't offer what I need

f) I think that the questions I have about maths and/or statistics are too basic for me to ask for help
g) I think that the questions I have are too advanced for MASH to help
h) Other (please state)

[skip to Q9]

5) [question designed to produce data on factors affecting whether non-users would seek support]. Would support for maths and statistics help you? Please indicate whether you agree with the following statements: [Likert scale 1-5 strongly disagree/strongly agree]
   a) I have the right level of understanding of maths and/or statistics to progress in my degree.
   b) Support to help me understand maths and/or statistics lectures and tutorials would be useful
   c) I would learn more from my own independent study of maths and/or stats if I could get some individual tuition.
   d) My assessed work would improve if I had individual support.
   e) Individual support for my maths and/or statistics study would increase my confidence in the subject.
   f) I would like more support with my maths and/or stats, but I don't know where to find it.

g) I think that the questions I have about maths and/or statistics are too basic for me to ask for help [skip to Q9]

6) [questions for students who have used MASH] How many times have you visited MASH for support? [1-2, 3-5, 5-10, 10+]

7) As a result of using MASH, please indicate whether you agree with the following statements: [Likert scale 1-5 strongly disagree/strongly agree]
   a) I have improved my understanding of lectures and tutorials
   b) I am better able to complete out-of-class work
   c) When I do not understand an area of maths and/or stats, I am better able to find out more about it
   d) My assessed work has improved
   e) I have the right level of knowledge about maths and/or statistics to progress in my degree
   f) I am more confident about maths and/or statistics

8) What aspect of the MASH service, if any, has had the most impact on your learning about maths and/or statistics?
9) Do you have any further comments or suggestions about the MASH service?

Thank you for completing this questionnaire. For more information the University of Sheffield's Maths and Statistics Help service, go to http://www.shef.ac.uk/MASH

MASH/LeTS 30 Jan 2009

Appendix 11 – ASSIST + Questionnaire

	Approaches to Studying	5	4	3	2	1
1	I manage to find conditions for studying which allow me to get on with my work easily.					
2	When working on an assignment, I'm keeping in mind how best to impress the marker.					
3	Often I find myself wondering whether the work I am doing here is really worthwhile.					
4	I usually set out to understand for myself the meaning of what we have to learn.					
5	I am good at memorising methods and processes					
6	I organise my study time carefully to make the best use of it.					
7	I find I have to concentrate on just memorising a good deal of what I have to learn.					
8	I look at the evidence carefully and try to reach my own conclusion about what I'm studying.					
9	I try to relate ideas I come across to those in other topics or other courses whenever possible.					
10	I tend to read very little beyond what is actually required to pass.					
11	I think I'm quite systematic and organised when it comes to revising for exams.					
12	I look carefully at tutors' comments on course work to see how to get higher marks next time.					
13	There's not much of the work here that I find interesting or relevant.					
14	I enjoy developing formulae when problem solving					
15	When I read an article or book, I try to find out for myself exactly what the author means.					
16	I'm pretty good at getting down to work whenever I need to.					
17	Much of what I'm studying makes little sense: it's like unrelated bits and pieces.					
18	When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.					
19	I prefer working with fully worked out examples in lectures					
20	Often I find myself questioning things I hear in lectures or read in books.					
21	I concentrate on learning just those bits of information I have to know to pass.					
22	I'm good at following up some of the reading suggested by lecturers or tutors					
23	I keep in mind who is going to mark an assignment and what they're likely to be looking for.					
24	When I look back, I sometimes wonder why I ever decided to					

	come here.					
25	When I am reading, I stop from time to time to reflect on what I am trying to learn from it.					
26	I like seeing the relationship between different formulae					
27	I work steadily through the term or semester, rather than leave it all until the last minute.					
28	I'm not really sure what's important in lectures so I try to get down all I can.					
29	I like to develop new steps in a procedure					
30	Ideas in course books or articles often set me off on long chains of thought of my own.					
31	When I read, I examine the details carefully to see how they fit in with what's being said.					
32	I gear my studying closely to just what seems to be required for assignments and exams.					
33	I like trying out lots of examples					
34	I usually plan out my week's work in advance, either on paper or in my head.					
35	I keep an eye open for what lecturers seem to think is important and concentrate on that.					
36	I'm not really interested in this course, but I have to take it for other reasons.					
37	Before tackling a problem or assignment, I first try to work out what lies behind it.					
38	I like to make use of processes I've learnt					
39	I generally make good use of my time during the day.					
40	I often have trouble in making sense of the things I have to remember.					
41	I like to play around with ideas of my own even if they don't get me very far.					
42	It's important for me to be able to follow the argument, or to see the reason behind things.					
43	I like to be told precisely what to do in essays or other assignments.					
44	I am good at using a formulae sheet					
KEY	5 = Agree, 4 = Agree somewhat, 2 = Disagree somewhat, 1 = Disagree, 3 = Neither agree nor disagree					

Table 65 – ASSIST+ Approaches to Studying Questions

Appendix 12 – ASSIST+ Questions groups for scales and sub-scales

Approach to Studying	Sub-Scale	Q1	Q2	Q3	Q4
Deep Approach	Relating Ideas	9	18	30	41
	Seeking Meaning	4	15	25	37
	Use of Evidence	8	20	31	42
Surface Approach	Lack of Purpose	3	13	24	37
	Syllabus- Boundness	10	21	32	43
	Unrelated Memorising	7	17	28	40
Strategic Approach	Alertness to Assessment Demands	2	12	23	35
	Organised Studying	1	11	22	34
	Time Management	6	16	27	39
Procedural Deep	Relating Processes	14	26	29	38
Procedural Surface	Memorising Processes	5	19	33	44

Table 66 – Scales and sub-scales for the ASSIST+ questionnaire

Appendix 13 – ASSIST+ Shorter version questions

	Approaches to Studying	5	4	3	2	1
1	I am good at memorising methods and processes					
2	I organise my study time carefully to make the best use of it.					
3	I think I'm quite systematic and organised when it comes to revising for exams.					
4	There's not much of the work here that I find interesting or relevant.					
5	I enjoy developing formulae when problem solving					
6	When I read an article or book, I try to find out for myself exactly what the author means.					
7	I'm pretty good at getting down to work whenever I need to.					
8	Much of what I'm studying makes little sense: it's like unrelated bits and pieces.					
9	When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.					
10	I prefer working with fully worked out examples in lectures					
11	Often I find myself questioning things I hear in lectures or read in books.					
12	I like seeing the relationship between different formulae					
13	I work steadily through the term or semester, rather than leave it all until the last minute.					
14	I'm not really sure what's important in lectures so I try to get down all I can.					
15	I like to develop new steps in a procedure					
16	Ideas in course books or articles often set me off on long chains of thought of my own.					
17	When I read, I examine the details carefully to see how they fit in with what's being said.					
18	I like trying out lots of examples					
19	Before tackling a problem or assignment, I first try to work out what lies behind it.					
20	I like to make use of processes I've learnt					
21	I often have trouble in making sense of the things I have to remember.					
22	I am good at using a formulae sheet					

Table 67 - ASSIST+ Shorter version AtS questions

Additional questions for ASSIST+ Shorter questionnaire

- *Which best describes your past experience of mathematics?*

Excellent = 5, Good = 4, Fair = 3, Bad = 2, Very Bad = 1

- *Can you elaborate on your choice?*
- *Which best describes your ability in mathematics?*

Excellent = 5, Good = 4, Fair = 3, Bad = 2, Very Bad = 1

- *How do you think your ability in mathematics improves or can be improved?*
- *Which best describes your feelings for mathematics?*

Find it interesting = 5, Find it enjoyable = 4, Indifferent = 3, Don't find it enjoyable = 2, Don't find it interesting = 1

- *What has been the major influence for this feeling for mathematics?*

Attitudes to mathematics						
1	Which best describes your past experience of mathematics?	Excellent	Good	Bad	Very Bad	Fair
2	Please can you elaborate on your choice (noting any significant experience)?					
3	Which best describes your ability in mathematics?	Excellent	Good	Bad	Very Bad	Fair
4	How do you think your ability in mathematics improves or can be improved?					
5	Which best describes your feelings for mathematics?	Find it interesting	Find it enjoyable	Don't find it enjoyable	Don't find it interesting	In-different
6	What has been the major influence for this feeling for mathematics?					

Table 68 - ASSIST+ Shorter version Additional Attitude questions

Appendix 14 – Teaching Preference Questions in ASSIST+

	Teaching Style Preferences	**5**	**4**	**2**	**1**	**3**
1	Lecturers who tell us exactly what to put down in our notes.					
2	Lecturers who encourage us to think for ourselves and show us how they themselves think.					
3	Exams which allow me to show that I've thought about the course material for myself.					
4	Exams or tests which need only the material provided in our lecture notes.					
5	Courses in which it's made very clear just which books we have to read.					
6	Courses where we're encouraged to read around the subject a lot for ourselves.					
7	Books which challenge you and provide explanations which go beyond the lectures.					
8	Books which give you definite facts and information which can easily be learned.					
KEY	5 = Definitely like, 4 = Like to some extent, 2 = Dislike to some extent, 1 = Definitely dislike, 3 = Unsure					

Table 69 – Teaching Preferences Questions

Teaching Preference	**Sub-Scale**	**Q1**	**Q2**	**Q3**	**Q4**
Deep Approach	Supporting Understanding	2	3	6	7
Surface Approach	Transmitting Information	1	4	5	8

Table 70 – Sub-Scales within Teaching Preferences Questions

Appendix 15 – Summary of mathematics modules

Institute	Codes	Module Titles	Credit Value	Level
RGU	CM1003	Quantitative Methods for Computing	15	1
RGU	CM1900	Quantitative Methods	15	1
RGU	CM1901_2	Quantitative Methods for Professional Accreditation	15	1
RGU	CM2900_1	Advanced Quantitative Methods for Engineers	15	2

Table 71 – Summary of RGU module details used in analysis

Institute	Codes	Module Titles	Credit Value	Level
UoS	COM1002	Foundations in Computer Science	20	1
UoS	ACS123	ACS Engineering Mathematics	10	1
UoS	MAS001_2	A-Level Students Returning after a Period	20	1
UoS	MAS140	Chemical Processing Engineering Mathematics	10	1
UoS	MAS143_4	Civil Engineering Mathematics	10	1
UoS	MAS145_6	Mathematics B (Electrical/Control/Aerospace) BTEC	10	1
UoS	MAS147_8	Mathematics A (Electrical/Control/Aerospace) AL	10	1
UoS	MAS149_50	Essential Mathematical Techniques (Mechanical Eng)	10	1
UoS	MAS154_5	Mathematics 1 (Materials)	10	1
UoS	MAS244	Mathematics III (Control)	10	2
UoS	MAS248	Mathematics III (Chemical)	10	2
UoS	MAS252	Further Civil Engineering Mathematics & Computing	10	2
UoS	MAS253	Mathematics for Engineering Modelling	10	2

Table 72 – Summary of UoS module details used in analysis

Appendix 16 – Chi-square distribution table

df	p = 0.05	p = 0.01	p = 0.001	df	p = 0.05	p = 0.01	p = 0.001
1	3.84	6.64	10.83	41	56.94	64.95	74.75
2	5.99	9.21	13.82	42	58.12	66.21	76.09
3	7.82	11.35	16.27	43	59.30	67.46	77.42
4	9.49	13.28	18.47	44	60.48	68.71	78.75
5	11.07	15.09	20.52	45	61.66	69.96	80.08
6	12.59	16.81	22.46	46	62.83	71.20	81.40
7	14.07	18.48	24.32	47	64.00	72.44	82.72
8	15.51	20.09	26.13	48	65.17	73.68	84.03
9	16.92	21.67	27.88	49	66.34	74.92	85.35
10	18.31	23.21	29.59	50	67.51	76.15	86.66
11	19.68	24.73	31.26	51	68.67	77.39	87.97
12	21.03	26.22	32.91	52	69.83	78.62	89.27
13	22.36	27.69	34.53	53	70.99	79.84	90.57
14	23.69	29.14	36.12	54	72.15	81.07	91.88
15	25.00	30.58	37.70	55	73.31	82.29	93.17
16	26.30	32.00	39.25	56	74.47	83.52	94.47
17	27.59	33.41	40.79	57	75.62	84.73	95.75
18	28.87	34.81	42.31	58	76.78	85.95	97.03
19	30.14	36.19	43.82	59	77.93	87.17	98.34
20	31.41	37.57	45.32	60	79.08	88.38	99.62
21	32.67	38.93	46.80	61	80.23	89.59	100.88
22	33.92	40.29	48.27	62	81.38	90.80	102.15
23	35.17	41.64	49.73	63	82.53	92.01	103.46
24	36.42	42.98	51.18	64	83.68	93.22	104.72
25	37.65	44.31	52.62	65	84.82	94.42	105.97
26	38.89	45.64	54.05	66	85.97	95.63	107.26
27	40.11	46.96	55.48	67	87.11	96.83	108.54
28	41.34	48.28	56.89	68	88.25	98.03	109.79
29	42.56	49.59	58.30	69	89.39	99.23	111.06
30	43.77	50.89	59.70	70	90.53	100.42	112.31
31	44.99	52.19	61.10	71	91.67	101.62	113.56
32	46.19	53.49	62.49	72	92.81	102.82	114.84
33	47.40	54.78	63.87	73	93.95	104.01	116.08
34	48.60	56.06	65.25	74	95.08	105.20	117.35
35	49.80	57.34	66.62	75	96.22	106.39	118.60
36	51.00	58.62	67.99	76	97.35	107.58	119.85
37	52.19	59.89	69.35	77	98.49	108.77	121.11
38	53.38	61.16	70.71	78	99.62	109.96	122.36
39	54.57	62.43	72.06	79	100.75	111.15	123.60
40	55.76	63.69	73.41	80	101.88	112.33	124.84

Appendix 17 – Mathematical Preparedness – Alternative review

The chi-square test used to examine significance of the differences between the *MEQ* levels for *MSU* categories for both institutes (Table 15 and Table 16) show that the results are significant. Although the highest mathematics support users were the *Well Prepared* students, the *Less Well Prepared* students are proportionally higher 47 (16.6%) out of the 283 and 53 (31.4%) out of the 174 *Less Well Prepared* entrants for RGU and UoS respectively compared to the *Well Prepared* entrants where the figures are 70 (9.4%) out of 745 and 159 (8.1%) out of 1871. The actual usage by the *Less Well Prepared* entrants was significantly higher than expected at both Institutes see highlights in Table 15 and Table 16 (grey giving the highest difference between observed and expected numbers).

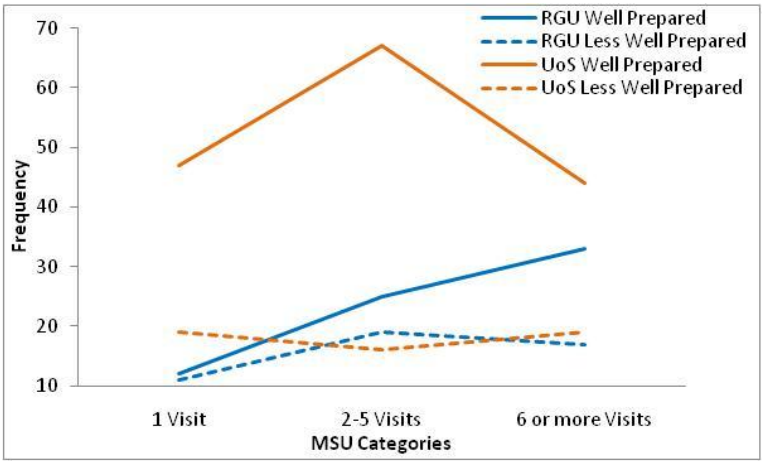


Chart 37 – MSU by preparedness for Institutes

There was also a significant difference in the age at entry means for these two groups, with a mean age of 18.43 and 19.59 for *Well Prepared* and *Less Well Prepared* entrants respectively. The longer term mathematics usage is significantly correlated to age for *Less Well Prepared* entrants as can be seen in Chart 38.

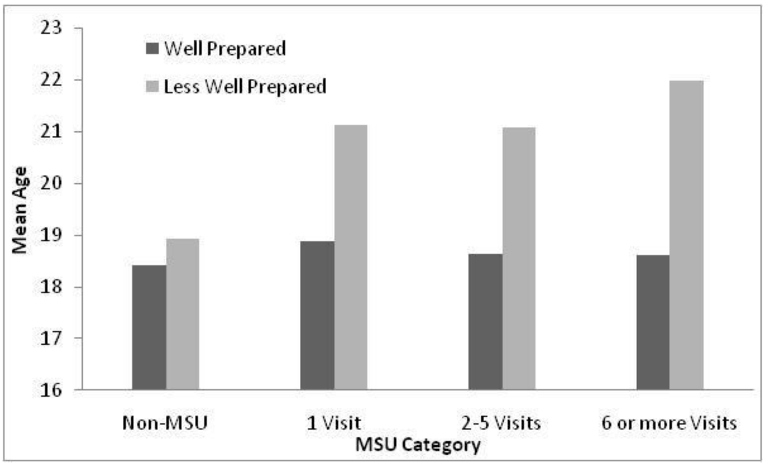


Chart 38 – Age means for entry preparedness by MSU categories

Finally Chart 39 and Chart 40 show the *MSU* visits by preparedness for RGU and UoS and, it appears that the institutes' have differing behaviours. RGU had better sustained engagement with mathematics support by students who were *Well Prepared* and whereas at UoS their engagement seems to fall down after 2-5 visits category. For the *Less Well Prepared* at UoS all the *MSU* categories attract similar usage but at RGU there was less sustained usage of support.

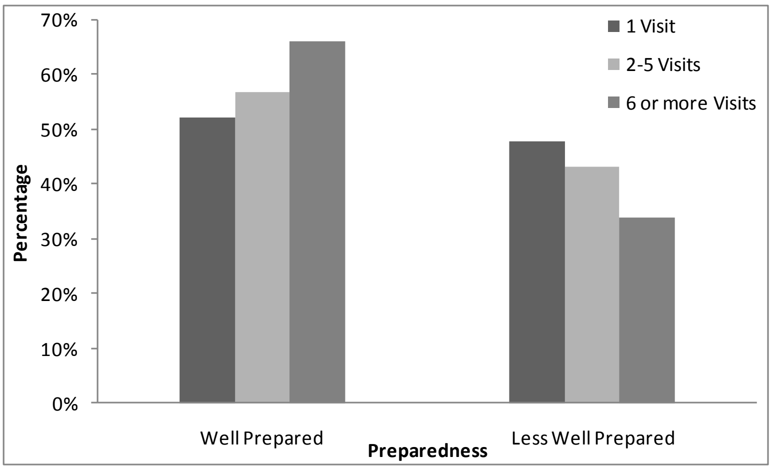


Chart 39 – RGU: MSU categories by mathematics preparedness

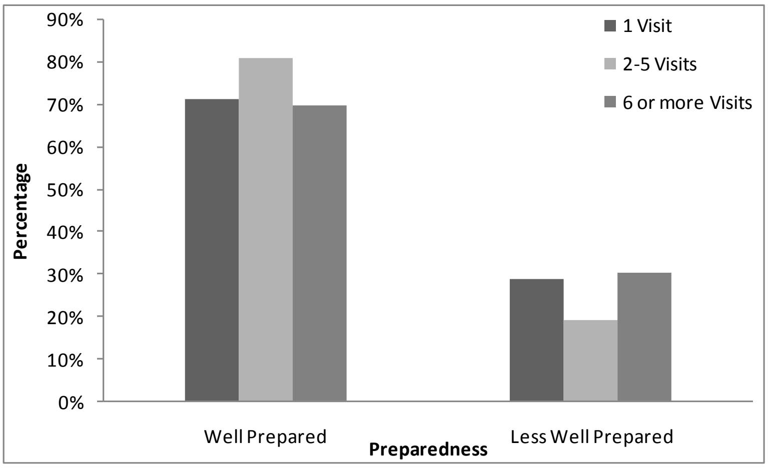


Chart 40 – UoS: MSU categories by mathematics preparedness

Overall the results suggest mathematics support was attracting the mathematically well prepared students possibly wanting to further improve their scores as seen in the study by (Pell and Croft 2008) and evidenced here in this research. The usage pattern of the *Less Well Prepared* and *Well Prepared* students was different at the two institutes, possible reasons apart from actual qualifications could be motivation, attitudes, confidence and approaches to studying, the latter being explored further in this research.

The *MEQ* scores represent the highest UCAS tariff points for the *MEQ* obtained before enrolment but do not indicate when these points were gained and because the tariff points are not continuous they will be analysed using non-parametric tests. The *BMDT* percentages give a better indication of students' actual mathematical knowledge at the start of the programme of studies whereas the *MEQ* points show the highest level of mathematics studied and does not take into account any weakening effect due to forgetting or/and lack of practice and use of mathematics. Although both MEQ and BMDT results do not give us the students' mathematical ability but does give us comparable measures of knowledge and is deemed useful.

Appendix 18 – AtS Principal Component Analysis Variance Table

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	3.262	40.776	40.776	3.262	40.776	40.776
2	1.524	19.047	59.823	1.524	19.047	59.823
3	1.069	13.366	73.189	1.069	13.366	73.189
4	.816	10.200	83.389			
5	.422	5.272	88.661			
6	.355	4.432	93.093			
7	.322	4.019	97.112			
8	.231	2.888	100.000			

Table 73 – Total Variance Explained

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	3.262	40.776	40.776	2.839	35.487	35.487
2	1.524	19.047	59.823	1.808	22.597	58.084
3	1.069	13.366	73.189	1.208	15.105	73.189
4	.816	10.200	83.389			
5	.422	5.272	88.661			
6	.355	4.432	93.093			
7	.322	4.019	97.112			
8	.231	2.888	100.000			

Table 74 – Total Variance Explained – Varimax rotation

Appendix 19 – Regression Model 1 tables

Correlations

		Actual L1 Marks AllMods	BMDT Percentage	Maths Entry Qualifications #
Pearson Correlation	Actual L1 Marks AllMods	1.000	.395	.219
	BMDT Percentage	.395	1.000	.286
	Maths Entry Qualifications #	.219	.286	1.000
Sig. (1-tailed)	Actual L1 Marks AllMods	.	.000	.000
	BMDT Percentage	.000	.	.000
	Maths Entry Qualifications #	.000	.000	.
N	Actual L1 Marks AllMods	278	278	278
	BMDT Percentage	278	278	278
	Maths Entry Qualifications #	278	278	278

Table 75 – Regression Model 1 - Correlations

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11157.692	2	5578.846	27.782	.000[a]
	Residual	55222.036	275	200.807		
	Total	66379.728	277			

a. Predictors: (Constant), Maths Entry Qualifications #, BMDT Percentage

b. Dependent Variable: Actual L1 Marks AllMods

Table 76 – Regression Model 1 - Anova

Descriptive Statistics

	Mean	Std. Deviation	N
Actual L1 Marks AllMods	63.49	15.480	278
BMDT Percentage	85.73	10.617	278
Maths Entry Qualifications #	5.58	.726	278

Table 77 – Regression Model 1 - Means

	Unstandardized Coefficients		**Standardized**			**95% Confidence Interval for B**		**Correlations**			**Collinearity Statistics**	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	4.547	8.414		.540	.589	-12.017	21.112					
BMDT Percentage	.528	.084	.362	6.306	.000	.363	.692	.395	.355	.347	.918	1.089
Maths Entry Quals	2.458	1.224	.115	2.008	.046	.048	4.868	.219	.120	.110	.918	1.089

Dependent variable – Module marks

Table 78 – Regression Model 1 - Means

Appendix 20 – Regression models including additional independent variables

From the *BMDT* and *MEQ* regression model in section it is clear that the results had a significant relationship with module results, therefore hierarchal regression was used with the independent variables *BMDT* and *MEQ* placed in block 1 with the ENTRY method of regression and the *AtS* Scales (second analysis using *AtS* subscales) in block 2 with STEPWISE method to explore influence.

The numbers of *AtS* cases in the MAS modules for *Non-MSU* and *MSU* were 56 and 15 respectively. The *AtS* scales were not significant and hence excluded using the STEPWISE method but to enable an analysis between *Non-MSU* and *MSU* it was important to retain the *AtS scores.* Therefore the ENTER method was used to force retention and significance values of the variables. The summaries are based on significance of 0.0005 for *BMDT* and only less than 0.5 for the other factors *MEQ*, *AtS Deep*, *Surface* and *Strategic* scales. The means and standard deviation of the variable are provided in Table 79. The ANOVA gives significant results with F=12.269 and df=2 for *BMDT* and *MEQ,* and for the *AtS* scales; F=5.976 and df=5 for the *BMDT, MEQ* and *AtS* scales. The summary statistics are provided in Table 79 and in-between correlations are given in Table 80. The only strong correlation being for *BMDT* with though there is also a moderate negative correlation between the *Deep* and *Surface AtS* scales.

Non-MSU	Mean	Std. Dev.	t	Sig.	B
BMDT Percentage	88.20	8.851	5.044	0.000	1.056
MEQ Grades	5.43	0.783	-1.577	0.121	-4.028
Deep Approach	15.43	2.739	-0.721	0.475	-0.547
Surface Approach	10.10	1.889	0.984	0.330	1.003
Strategic Approach	14.61	2.929	1.792	0.079	1.097

Table 79 – UoS summaries for BMDT, MEQ and AtS scales for Non-MSU

For Non-MSU	Level 1 Marks	BMDT	MEQ	Deep	Surface
BMDT Percentage	0.534				
MEQ Grades	-0.041	-0.310			
Deep Approach	0.029	-0.229	0.425		
Surface Approach	0.122	-0.091	0.217	0.374	
Strategic Approach	0.168	0.023	0.015	-0.088	0.146

Table 80 – UoS module Level 1 marks correlation to BMDT and AtS scales for Non-MSU

The multicollinearity of the independent variables was deemed acceptable with the Tolerance and VIF within the required thresholds. The R^2 in this model was 0.374 and the adjusted R^2 is 0.311 making the model good and meaning that 37.4% of the variance in the module marks can be explained by the factors. The resulting regression model for this analysis is given in Equation 6.

$$Y_{Non\text{-}MSU\_L1} = -19.513 + 1.056(BMDT) - 4.028(MEQ) - 0.547(Deep) + 1.003(Surface) + 1.097(Strategic)$$

Equation 6 – UoS regression model for performance by BMDT, MEQ and AtS scales for Non-MSU

Due to compromising on the significance level and small numbers of the students in the groups this analysis is not statistically useful but retained to illustrate potential use. The potential of the model is to use on *MSU* students' *BMDT*, *MEQ* and *AtS* scores to predict module marks. Summarised in Table 81 is the result of this; the student numbers are very low therefore the whole cohort of students within the *MSU* categories with module marks for *Actual Marks*, have been used whereas only the students within these groups with *BMDT, MEQ* and *AtS* scores (and subscales in Table 81) to provide the predicted scores. This has been carried simple as a demonstration as application of the models (Equations 6 and 7) as it is not acceptable to retain student who only have results for one of the pre or post-test in the analysis.

For 1 and 2-5 visits the actual marks appear to be better than the predicted marks (0.8 and 23.49 respectively). For the 2-5 visits category it can mean the difference between passing or failing (4 students). The effect size was *large.*

MSU Category	Mark	Cases	Mean	Std. Dev.	Std. Error	Mean Plus Std. Error	Mean Minus Std. Error	Cohen's *d*
1 Visit	Actual	6	74.50	19.31				
	Predicted	6	61.46	18.92	7.730	69.19	53.73	0.04
2-5 Visits	Actual	4	21.17	5.686				
	Predicted	4	35.23	16.87	8.433	43.66	26.80	1.0
6 and more	Actual	8	44.21	25.64				
	Predicted	8	52.18	24.18	8.550	60.73	43.63	-0.07

Table 81 – Actual and predicted marks for mathematics support usage categories and effect size for mathematics ability and AtS as predictors

Analysis including the *AtS* subscales in the regression gave the summary statistics provided in Table 82. The *AtS* subscales were not significant using the STEPWISE method and to enable an analysis between *Non-MSU* and *MSU* the ENTER method is used to force retention of *AtS* subscales. The ANOVA gives significant results with F=12.269 and df=2 for *BMDT* and *MEQ* and F=3.540 and df=10 for the *AtS* subscales. Only strong (above 0.3) correlations in the in-between factors are given for these factors in Table 83*.*

Non-MSU	Mean	Std. Dev.	t	Sig.	B
BMDT Percentage	88.20	8.851	4.669	0.000	1.024
MEQ Grades	5.43	0.783	-1.660	0.104	-4.797
DP_IR	15.25	3.386	-0.041	0.967	-0.035
DP_UE	15.29	3.049	-0.570	0.572	-0.574
DP_SM	14.96	3.156	-1.164	0.251	-0.949
DP_PRP	16.23	3.116	0.813	0.421	0.798
SR_LP	6.84	2.878	1.597	0.117	1.092
SR_SB	13.36	3.170	-0.264	0.793	-0.167
ST_OS	14.55	3.068	-0.585	0.562	-0.488
ST_TM	14.66	3.375	1.847	0.071	1.380

Table 82 - UoS module Level 1 marks correlation to BMDT and AtS subscales for Non-MSU

Non-MSU	Level 1 Marks	BMDT	MEQ	DP-RI	DP-UE	DP-SM	DP-PRP	SR-LP	SR-SB	ST-OS
BMDT	0.534									
MEQ										
DP_RI										
DP_UE			-0.418	0.697						
DP_SM			-0.303	0.615	0.556					
DP_PRP				0.706	0.726	0.642				
SR_LP										
SR_SB					-0.327	-0.335				
ST_OS										
ST_TM										0.652

Table 83 - UoS module Level 1 marks correlation to BMDT and AtS subscales for Non-MSU

The R^2 in this model was 0.440 (somewhat different form the R^2 adjusted of 0.316 hence not a very good model) giving an influence on variance of 44%. The resulting regression model for this analysis is given in Equation 7.

$Y_{L1\_Non\text{-}MSU} = -2.630 + 1.024(BMDT) - 4.797(MEQ) - 0.035\ (DP\_RI) - 0.574\ (DP\_UE) - 0.949\ (DP\_SM) + 0.798\ (DP\_PRP) + 1.092\ (SR\_LP) - 0.167(SR\_SB) - 0.488(ST\_OS) - 1.380(ST\_TM)$

Equation 7 – UoS regression model for performance by BMDT and AtS subscales for Non-MSU

Using this model on *MSU* students actual marks are very good compared to the predicted marks but the small number of cases and the large numbers of factors in the model make these results (Table 84) meaningless, verified again by the negative predicted score for 2-5 visits in Table 82.

MSU Category	Mark	Cases	Mean	Std. Dev.	Std. Error	Mean Plus Std. Error	Mean Minus Std. Error	Cohen's *d*
1 Visit	Actual	53	62.26	19.98				
	Predicted	6	25.15	20.11	8.210	33.36	16.94	1.9
2-5 Visits	Actual	72	58.72	24.17				
	Predicted	4	-7.108	11.58	5.789	-1.32	-12.90	2.8
6 and more	Actual	57	50.61	24,37				
	Predicted	8	10.36	25.18	8.902	19.26	1.46	1.7

Table 84 – Actual and predicted marks for mathematics support usage categories and effect size for mathematics ability and AtS as predictors

The results of the regression analysis consistently indicate the positive effect of mathematics support. The weakness of the analysis is the small numbers in the *MSU* categories and the lack of statistical significance for the *AtS* scales and subscales in the regression models. However these are not discarded because of the discussion in section 5.2 on the value added effect of mathematics support and the introduction of *AtS* scales and subscales in the regression analysis is adding potential new influential factors.

Appendix 21 – Non-MSU with failed mathematics modules and predicted marks

Actual Module Mark	VAS due to Maths support	Predicted Mark	Students
12	16.6	28.6	1
24	16.6	40.6	1
25	16.6	41.6	1
25.5	16.6	42.1	1
28	16.6	44.6	1
30.5	16.6	47.1	1
31.5	16.6	48.1	1
32	16.6	48.6	1
32.5	16.6	49.1	1
34	16.6	50.6	1
35	16.6	51.6	1
35.5	16.6	52.1	2
36	16.6	52.6	3
36.5	16.6	53.1	2
37	16.6	53.6	1
38	16.6	54.6	1
		Total Students	**20**

Non-MSU Students With predicted marks After maths support		
Fails	1	5%
Passes	19	95%

Actual MSU Students summary		
Fails	12	35%
Passes	22	65%

Table 85 – MAS145_6 Module Marks

Actual Module Mark	VAS due to Maths support	Predicted Mark	Students
17	2.7	19.7	2
20	2.7	22.7	1
21	2.7	23.7	1
23.5	2.7	26.2	3
26	2.7	28.7	2
28	2.7	30.7	1
29.5	2.7	32.2	1
32	2.7	34.7	1
34.5	2.7	37.2	1
36	2.7	38.7	1
36.5	2.7	39.2	2
37	2.7	39.7	2
37.5	2.7	40.2	1
38	2.7	40.7	2
38.5	2.7	41.2	1
39.5	2.7	42.2	2
		Total Students	**24**

Non-MSU Students With predicted marks After maths support		
Fails	16	67%
Passes	8	33%

Actual MSU Students summary		
Fails	3	7%
Passes	37	93%

Table 86 – MAS147_8 Module Marks

Actual Module Mark	VAS due to Maths support	Predicted Mark	Students
4	22.8	26.8	1
5	22.8	27.8	1
8.5	22.8	31.3	1
11.5	22.8	34.3	1
19	22.8	41.8	1
20	22.8	42.8	1
21	22.8	43.8	1
22	22.8	44.8	1
23	22.8	45.8	1
24	22.8	46.8	1
24.5	22.8	47.3	1
26	22.8	48.8	2
28	22.8	50.8	2
28.5	22.8	51.3	1
29	22.8	51.8	2
29.5	22.8	52.3	1
30	22.8	52.8	1
31	22.8	53.8	2
31.5	22.8	54.3	1
33	22.8	55.8	2
33.5	22.8	56.3	2
34	22.8	56.8	2
34.5	22.8	57.3	2
35	22.8	57.8	2
35.5	22.8	58.3	1
36	22.8	58.8	4
36.5	22.8	59.3	3
37	22.8	59.8	3
37.5	22.8	60.3	2
38	22.8	60.8	2
38.5	22.8	61.3	1
39	22.8	61.8	1
		Total Students	**50**

Non-MSU Students With predicted marks After maths support		
Fails	4	8%
Passes	46	92%

Actual MSU Students summary		
Fails	8	23%
Passes	27	77%

Table 87 – MAS149_50 Module Marks